TREATED SEWAGE/PROCESS WASTEWATER RECYCLE STUDY ROCKY FLATS PLANT SITE

Tasks 11 and 13
of the
Zero-Offsite Water-Discharge Study

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EXECUTIVE SUMMARY

This report is one of several being conducted for and in the development of, a Zero-Offsite Water-Discharge Plan for Rocky Flats Plant (RFP) in response to Item C.7 of the Agreement in Principle between the Colorado Department of Health (CDH) and the U.S. Department of Energy (DOE) (ASI, 1990a). The CDH/DOE Agreement Item C.7 states "Source Reduction and Zero Discharges Study: Conduct a study of all available methods to eliminate discharges to the environment including surface waters and groundwater. This review should include a source reduction review."

Specifically, this report addresses the potential for reuse (recycling) of domestic wastewater treatment plant effluent and the required treatment process train to achieve a level of water quality suitable for selected water demand centers at the RFP. Additionally, this report identifies process water reuse locations within RFP.

A water balance for the entire plant was developed. For calendar year (CY) 1989, 121 Million Gallons (MG) of water was purchased from the Denver Water Board (DWB), while 74 MG of Sanitary Treatment Plant (STP) effluent was discharge. By purchasing 121 MG of raw water from the DWB, RFP is importing approximately 43 tons of salts including lead, selenium and strontium into the plant.

Had the sanitary effluent in CY 89 been recycled, RFP could have reduced DWB purchases to meet the plant evaporation loss of approximately 55 million gallons per year (MGY). This would have also resulted in RFP reducing salts purchased from the DWB to 19 tons.

System Alternatives

Water reuse was the subject of a study by C. Rose in 1990 wherein existing potable water facilities at RFP would be converted to non-potable and vice versa. Alternative No. 1 of this study presents the non-potable reuse of highly treated wastewater with use of existing raw water and potable water distribution systems as is.

In Alternative 1, the existing raw water system would be extended to convert cooling towers and air washers currently utilizing domestic potable water. Loads that currently use domestic cold water that could use treated wastewater effluent would be added to the system.

Alternative 2 would require the switch of existing potable distribution facilities to non-potable and vice versa. Extensive interior and exterior plumbing modifications would be required. Only sinks, showers and food processing operations would be served by the domestic system. An advantage of Alternative 2 would be that the water balance would be self-correcting.

Alternative 3 provides for the use of highly treated wastewater as a raw water input to the existing potable/non-potable systems. At present, direct potable reuse is not practiced in the United States.

Each of the three alternatives provides for the recycle/reuse of highly treated sanitary wastewater generated at RFP. One obvious benefit of onsite water reuse is that pollution control costs are predictable for a long period of time. At the same time, all internal water users would be dealing with consistent and controllable water quality. Additionally, on and offsite liabilities would be controlled rather than uncontrolled i.e., political, cultural, economic. This applies to both liquid and solid streams.

Task 10, Sanitary Treatment Plant Evaluation presents an examination of the existing RFP STP performance capability, the need for upgrading same and any required increase in plant capacity. The issues of Process Water Recycle, Task 11, and Treated Sewage/Process Water Recycle, Task 13, are combined in this document. Task 12, Reverse Osmosis/Mechanical Evaporation will evaluate specific physical facilities required to accomplish the treatment level for reuse/recycle, as applied to both wastewater liquid and solids residuals.

Recommendations

As the result of this study, it is recommended that the RFP implement storage and distribution Alternative 1. This alternative utilizes RFP potable and raw water delivery systems currently in place. High quality treated wastewater would be added to the raw water supply system only and additional raw water use centers added to the raw water line. It is estimated that Alternative 1 would cost $1,670,000. This assumes pumping of the STP effluent from Building 995 to a point near the RFP entrance. Another option with Alternative 1 would be to site the effluent treatment facility near the current STP. This option would require less pipe and be more cost effective than siting the effluent treatment facility near the RFP entrance. No wetlands would be impacted with proposed construction. Treatment of wastewater during construction of facilities would be maintained at all times.

Implementation of Alternative 1 includes facilities for treatment of RFP wastewater to quality levels suitable for reuse. These facilities will be more fully described in Task 12, Reverse Osmosis/Mechanical Evaporation. Such treatment facilities must have strong administrative and operations management throughout the design, construction and operation/maintenance phases of the project. An evaluation matrix reflecting consideration of eleven site specific considerations and weighting factors supported the selection of Alternative 1 for implementation. The matrix is presented in Section 4.

Also recommended for the RFP is an aggressive water conservation program. This program should address water system leakage, low water-use fixtures, extensive metering, a meter maintenance program and a system-wide water conservation education program.

TREATED SEWAGE/PROCESS WASTEWATER

RECYCLE STUDY

Rocky Flats Plant Site

1.0 INTRODUCTION

Sound water resources management must include the potential reuse of properly treated wastewater as an alternative to meet current and projected water demands. Public opinion regarding the reuse alternative is shaped by water conservation, public health protection, treatment and distribution costs, and environmental factors. These factors describe the basic goals of this study, i.e., source reduction and zero discharge. The Environmental Protection Agency (EPA) views closed-cycle water systems as an ultimate goal for industrial plants, for pollution control purposes alone (EPA, 1980). Zero discharge requires taking a source-by- source inventory of waste, developing specific means to limit consumption (water conservation), defining the quality of water required for in-system utilization (reuse) and establishing a treatment level for such reuse.

Reuse can be divided into sequential reuse, the use of one process effluent as input to another process, and recirculation, recycling water within a process. A combination of the two is typically implemented.

2.0 CURRENT WATER MANAGEMENT PRACTICES

2.1 Study Area Characteristics

RFP is located about 15 miles northwest of Denver, Colorado. The plant occupies about 10 square miles. Both surface and groundwater flow is generally from west to east. From west to east the land surface falls about 300 feet (ASI, 1988a). Because wastewater treatment facilities are near the eastern limit of the plant, wastewater reuse facilities must include pumping to return water to any distribution and storage facilities to be utilized for reuse.

2.2 Water System

All raw water used at RFP is purchased from the Denver Water Board (DWB) and is drawn from two sources: Ralston Reservoir and the South Boulder Diversion Canal that feeds the reservoir.

Ralston Reservoir is a water supply facility located 5.5 pipeline miles south-southwest of the plant site. Water is pumped from the base of the dam in a single 10 inch diameter cast iron supply line. Maximum pumping capacity is approximately one million gallons per day (MGD). About one third of the yearly RFP water is supplied by Ralston Reservoir during the November-April period. From May to October, the remaining two-thirds of the necessary raw water is supplied by a gravity flow pipeline from the seasonal flow in the South Boulder Diversion Canal, passing 1.5 miles west of the Plant. Pumping costs are reduced by using two sources on a seasonal basis, i.e., pumping only during the winter non-irrigation period.

All raw water purchased from the DWB flows into the raw water storage pond one-half mile west of the Rocky Flats Water Treatment plant in Building 124. The open, asphalt lined pond has a nominal capacity of 1.5 million gallons with one foot of free-board.

With an average year-round water use of 300,000 gallons per day, the pond has about a 5 day storage capacity. It is possible to bypass the pond and allow raw water to flow directly to the treatment facility located in Building 124.

Raw water purchases from the DWB are tabulated below and depicted graphically in Figure 1. From 1983 to 1986, the plant experienced almost a doubling of personnel (3,000 to 6,000) with an attendant increase in raw water purchases.

TABLE 1
RAW WATER PURCHASED FROM DENVER BOARD OF WATER COMMISSIONERS

Year	Raw Water Purchased (gallons)
1980	108,038,000
1981	92,098,000
1982	101,591,000
1983	106,469,000
1984	125,768,000
1985	131,197,000
1986	133,677,000
1987	127,093,000
1989	131,394,000

Only a portion of the raw water from the storage pond enters Building 124 for treatment to potable quality; the remainder is bypassed to feed the RFP raw water system. The domestic potable water distribution system and the raw water distribution system are shown in Figures 2 and 3, respectively.

2.3 Water Treatment Facility

Building 124 is the potable or domestic water treatment facility for the RFP. Designed to treat one million gallons per day (MGD) of flow, the facility consists of a microstrainer for algae removal in summer months, conventional alum and polymer addition for flocculation and clarification, lime and caustic soda addition for pH control, chlorine and polymer addition prior to sand filtration and final chlorination in the clearwell.

The water treatment plant is not in continuous operation during each day i.e., the plant is started, tanks are filled and the plant shutdown. Product water quality variations have been experienced because of these factors (ASI, 1990b).

Storage capacity for finished drinking water is as follows:

Clearwell	250,000 gallons
Aboveground Storage	500,000 gallons
Elevated Storage	300,000 gallons
Fire Protection Storage	500,000 gallons
	1,550,000 gallons

Fire protection water storage is located in the personnel security zone (PSZ) and is reserved for fire use only. Normal filter backwashes and blowdowns account for approximately 4 percent of the incoming flow and are recycled to the headworks of the facility. Sludges are pumped to drying beds for subsequent removal.

2.4 Water Usage

Purchased raw water is the primary source of water for the plant. Raw water is used primarily for boiler and cooling tower makeup water and two areas of lawn irrigation, outside buildings 130 and 850, during summer months. Potable water is currently used for all direct human uses: fire protection, laundry, film developing, cooling tower makeup, air washers, landscape irrigation and process water. Process water use includes chemical preparation, machine and instrument cooling and laboratory needs.

2.4.1 Cooling Tower Operations

All of the cooling towers used at the RFP are mechanical-draft wet towers that cool buildings or process waters by transferring heat to the atmosphere through direct mixing of air and water. Electrically driven fans provide air flow through the towers, where excess heat is picked up by water as it circulates through cooling coils in the buildings' heating, ventilating, air-conditioning and process heat exchangers. A portion of the water is evaporated as it mixes with cool air flowing through the tower, transferring the excess heat to the atmosphere. Cooling tower operation and evaporation rates are dependent on ambient air temperatures and tower heat load. To minimize biological growth and corrosion in the cooling towers, various biocides are added to the recirculating piping within the cooling tower.

From plant utility records, cooling tower water usage for CY 89 was calculated to be 57 MG with approximately 40 MG being evaporated and 17 MG being blowndown to the sanitary sewer. At RFP, most cooling towers are blowndown when total dissolved solids (TDS) reach 700-1000 mg/l. During cooling tower operations, water is added to replace water blowndown or lost by evaporative heat dissipation, to maintain quality. Three major buildings, 559, 771, and 865, currently use domestic or potable water rather than raw water for cooling tower operations.

2.4.2 Air Washer/Evaporative Cooling Operations

Five buildings use air washers in the summer months for evaporative cooling. Original air washing equipment at RFP used domestic potable water in evaporative "swamp coolers" to cool air in summer months for employee comfort. A new system of indirect cooling, already installed in Buildings 130 and 131 and the 400 and 800 series buildings, uses considerably less water. This type system is expected to be implemented in Building 771 in the near future. Raw water could be used to satisfy these direct cooling systems. Air washers accounted for nearly 12 MGY with approximately 3.5 MG of blowdown going to the sanitary sewer and 8.5 MG being evaporated.

2.5 Sanitary Wastewater System

Sanitary wastewater is treated at building 995 near the plant's eastern boundary. Features of the treatment facility include flow equalization (Building 990), 12" vitrified clay pipe sanitary sewer connecting Building 990 and Building 995, influent flow splitting, wastewater solids comminution (grinding), parallel activated sludge facilities (primary clarifiers, aeration basins and final clarifiers), chemical addition, tertiary clarification, pressure sand filtration, chlorination-dechlorination, and discharge. The treatment facility is operated consistent with its discharge permit; new permit conditions are currently being negotiated.

STP influent and effluent quality characterization is described fully under Task 10, Sewage Treatment Plant Evaluation Study. In summary, the plant's liquid stream is discharged to South Walnut Creek which is tributary to the B-Series ponds on this drainage. In the past, effluent stored in Pond B-3 was pumped to spray irrigation land sites nearby. This system is presently not in service. Any effluent not consumed via evaporation, transpiration, percolation or other losses is eventually tributary to the Great Western Reservoir downstream. Great Western serves as a raw water storage reservoir for the city of Broomfield prior to treatment for potable water delivery. It has been reported that minor releases of radioactivity and chemical contaminants have reached this reservoir in the past.

Sludge handling at the STP has been a bottleneck in the past. Waste solids generated at the plant as primary and waste activated sludge have historically been dried in sludge drying beds, boxed and shipped for disposal offsite as low-level radioactive waste. In reviewing sludge quality data collected at the plant, it was noted that the sludge contains about 2 percent silver by weight. If this were consistent for the 78,000 pounds of dry sludge produced each year, some 1500 pounds of silver could be recovered. This is worth about $150,000.00 on an annual basis.

The current wastewater plant liquid and solid handling capabilities are not adequate to address flows projected to increase to 0.4 MGD (ASI, 1990b). Additionally, nitrification-denitrification requirements expected as part of the RFP discharge permit negotiations can not be met with existing facilities. Several short term plant modifications are being completed to address current problems. These include the sludge handling improvements noted earlier, influent/effluent instrumentation, aeration basin diffusers, digester gas control modifications, chemical feed systems, auto-chlorination/dechlorination and administrative area modifications.

Approximately 1 MGY of water is lost to the atmosphere from evaporation and sludge drying or removal. A flow schematic of the sewage treatment plant is contained in Appendix A.

2.5.1 Sanitary Sewer Inputs

Most water conservation/use studies have been performed in domestic home environments or specific commercial/industrial settings. Based on data from RFP utility records, total domestic water usage for CY 89 is estimated at 68 MGY. The following calculations estimate annual human usage of the domestic water supply:

1. Shower Usage:

   (0.6)(6300 employees)(14 gal/shower)(250 days/year) = 13 MGY

   Source: (ASI, 1988)

2. Sanitary Inputs:

   (6300 employees)(2 flushes/day)(4 gallons/flush)(250 day/yr.) = 12 MGY

   Source: (ASI, 1988)

3. Drinking Water, Handwashing:

   (6300 employees)(2 gallons/day)(250 days/year) = 3 MGY

   Source: (ASI, 1988)

4. Food Processing Cafeterias:

   2/3 of employees eat at cafeterias:

   (2/3)(6300 employees)(3 gallons/employee)(250 day/year) = 3 MGY

   (250 Food Service Employees)(15 gal./day)(250 day/year)= 1 MGY

   4 MGY

Source: Smith and Loveless, "Notes on Activated Sludge", B. Goodman

Total demand for human use:	13
	12
	3
	4
	32 MGY

The balance, 36 MGY, represents potable water use by industrial processes beyond raw water use for these same processes.

2.6 Process Wastewater System

Each building having production and development facilities is equipped with process wastewater collection systems totally isolated from the sanitary sewer collection system. Liquid process wastes include the following:

- process drains,
- decontamination showers,
- laboratory sinks,
- janitor sinks,
- floor drains,
- laundry wastes,
- organic wastes,
- machine oils,
- lubricants, and
- solvents.

Process waste pipelines connect each production and development building to a single separate waste treatment facility in Building 374 as shown in Appendix B. Prior to transfer to Building 374, all liquid wastes are analyzed to determine pH and radioactivity. The liquid streams entering Building 374 for waste treatment are stored in tanks according to their composition and intended routing. The collection system, along with a plant schematic, is illustrated in Appendix B.

2.6.1 Process Waste Treatment

In Building 374, acidic wastes are neutralized with caustic soda and filtered to remove solids. In general, these wastes are pumped to chemical reaction vessels where a multi-stage treatment process begins. This process includes precipitation, flocculation and clarification. Effluents are monitored for the presence of radioactive substances prior to being transferred to the evaporation system in Building 374.

Supernatant from the clarifiers is mixed with other low level wastes and introduced to a multiple effect forced evaporator. Concentrate from the last effect is fed to a spray dryer. The resulting salt product is immobilized with cement to form saltcrete which is stored onsite awaiting ultimate removal and disposal. Product water from all evaporator stages is used for boiler plant makeup and the Building 371 cooling tower.

Process waste sources, volumes and final uses for CY 89 and CY 90 are given in Figures 4 and 5. The Building 374 evaporator was originally designed to process 21 MGY of process waste, but ongoing maintenance, repair, corrosion and normal wear has reduced capacity to two-thirds of the original design, or 13-14 MGY.

Included in the yearly total flow of 13 MGY of process wastewater is interceptor trench flow from north of the 207 Ponds. This flow accounts for 4-5 MGY with the majority of the flow occurring in the four-month spring season. The collected water is presently stored in the 207 ponds and Tank 231 before treatment in Building 374.

Product water from Building 374 is currently used for makeup water for the boiler in Building 443 and the cooling tower in Building 371.

Because process waste treatment is critical to overall plant operation, a backup evaporator may be needed to provide additional or redundant capacity. Holding ponds used in the past are scheduled for closure, and present tankage is probably insufficient to store process water, interceptor trench waters or other difficult-to-treat waters at times when the evaporator is running at capacity. Any evaporator down time would only compound the problem given the limited storage capacity available.

2.6.2 Process Waste Minimization

Several EG&G Engineering Job Orders (EJOs), have been proposed that would impact process waste and water recycling. The EJOs are listed below:

Authorization No.	Title
402076	Pond C-2 Recycle
402079	Ponds A-4 and B-5 Recycle
401004	Laundry Water Recycle Study
492146	Laundry Water RO System Study
482167	Building 460 DI Water Recycle Study
374424	X-OMAT Wash Recycle Study
492051	Shower Water Reduction - Site
402088	Laundry Rinse Water Recycle
492264	Building 771 Condensate Recycle

Operations in the laundry facility produce large volumes of wastewater that require treatment in Building 374. One method of reducing the amount of this waste, proposed under EJO 401004, is to recycle water within the laundry by reusing water from the third cycle rinse for the first cycle wash. The reduction in water usage is estimated to be 2 MGY. The project will be submitted for expense funding and implementation in FY 1991. Reverse osmosis treatment of the laundry waste has also been proposed in the Laundry Water Study Authorization 492146.

Under EJO 374424, Pacex processors will be installed to reduce the silver dioxide concentration of wastewater discharged from film processing in buildings 444, 460, 707, 779, and 991 to the Building 374 evaporator. This project will result in approximately 7.6 MGY of raw water being conserved annually. Construction is slated to begin in FY 1990 and will continue into FY 1991.

A major human use of water is employee showering after the day shift. EJO 492051 details the replacement of existing shower heads in all shower facilities (except some of the showers in Building 883) by a proven water saving type shower head to save from 25-30% percent. The project will be submitted for expense funding and installation in FY 1991.

As detailed in EJO 482167, sanitary wastewater from eight cascade rinse tanks will be rerouted into a 100 gallon tank for recycle. This wastewater is of sufficient quality for recycle to the deionized water return loop. This project will result in a savings of approximately 2 MGY. The engineering scope and estimate has been submitted for FY 1991 funding authorization. If approved, the project will be implemented in FY 1991.

During FY 1988, the last full year of operation, a total of over 131,000 gallons of liquid effluents were produced by the ion exchange facilities. Preliminary calculations have shown that the quantity of wastewater produced by the ion exchange system could be reduced by optimizing column configuration and operation parameters. A computer model will be employed to aid in optimizing the design and operation parameters of the ion exchange systems in Building 771.

Aqueous waste generated in Building 443 consists primarily of boiler blowdown and regeneration water from the demineralizers and condensate polishing units. Under the FY 1991 Draft Work Plan for Waste Minimization, the boiler blowdown water would be rerouted to the sanitary sewer. Condensate at Building 443 is classified as a hazardous waste by derivation. Because the condensate is partially derived from hazardous liquid waste (evaporated and recondensed in Building 374), strict application of EPA rules means that the condensate is also considered a hazardous waste. A special permit will be required from the state of Colorado to allow boiler plant condensate to be disposed of in the sanitary sewer.

Although steps have been taken to eliminate noticeable leaks and reduce unnecessary use, the vast majority of RFP employees have not been involved in a systematic water conservation education program, whether oriented to domestic or process waters. Process waste minimization is currently being studied by ASI under Task 19 of the Zero Offsite Water Discharge Project.

2.6.3 CY 89 and CY 90 Water Balances

In formulating a current RFP-wide water balance, the following assumptions were made. The only reliable water data were assumed to be the total amount purchased from the DWB, the domestic and raw water use established by meters and the total wastewater flow. Lack of more extensive, accurate data necessitated back-calculation, forcing totals and using informed guesses. The results represent a good engineering estimate using available data. Using the best available utility data, water balances for CY 89 and CY 90 are presented in Figures 6 - 9. Process water and sanitary water balances for individual buildings and discrete areas are given in Appendix C.

3.0 RECYCLING SYSTEMS

3.1 Historical

A program of water reuse at RFP was begun in 1972 (Rockwell, 1987). Studies and proposals to reuse water via reverse osmosis (RO) treatment for dissolved salt management were accepted and implemented in 1979. A commitment to close the water cycle was made to both the DOE and EPA at that time. The primary purpose in constructing the reverse osmosis facility was to provide for a closed water cycle ensuring that no sanitary effluent would be discharged into downstream potable supplies. Recovered water was used to replace purchased raw water used for the cooling towers. When the reverse osmosis plant was not in operation, effluent was spray irrigated as noted earlier.

When using the reverse osmosis system, wastewater effluent was pumped from the chlorine contact basin at Building 995 to Pond 207 B South. This pond served as a flow equalization facility prior to treatment for reuse in Building 910. Reverse osmosis reuse treatment facilities included the following:

- chlorine addition
- downflow pressure filtration
- zeolite softening
- diatomaceous earth (DE) filtration
- pH reduction
- heat addition to 77°F
- three stage reverse osmosis
- pH adjustment
- tank storage
- biocide and corrosion inhibitor addition

Since its construction and initial operation, numerous problems and malfunctions were experienced (Rockwell, 1976). The problems included instrumentation/controls, piping/plumbing, short run cycles for pretreatment equipment, improper chemical conditioning, microbiological contamination/fouling and others. Significantly, the estimated quantity of reverse osmosis brine requiring ultimate handling exceeded design quantities by a factor of 10. This placed an evaporation burden on the existing mechanical evaporation system such that its capacity was exceeded. The reverse osmosis reuse facilities were effectively removed from service in 1984 and current plans include complete abandonment of existing facilities and equipment associated with its use.

The contaminant rejection capabilities of reverse osmosis and other membrane systems have been well documented over the last 20 years (Rockwell, 1980, 1981, 1981b). The demineralization of sand-filtered secondary treatment plant effluent by reverse osmosis has been documented by the EPA for work done in the late 1960's (EPA, 1977). An examination into the effectiveness of reverse osmosis treatment for the removal of low concentrations of radioactive material at RFP indicated that greater than 95 percent removal of uranium, plutonium and americium was attained. Removals were experienced in both pretreatment and reverse osmosis facilities. The 95% removal rate did not, however, outweigh the attendant problems.

3.1.1 Rose Proposal

C. Rose proposed a reuse concept for the purpose of minimizing offsite discharges of sanitary and process wastewater at RFP. The proposal effectively addressed the following problems:

- Offsite discharge and spray irrigation are undesirable
- Sufficient loads for water are not currently accessible
- Constantly changing internal water balances
- The existing reverse osmosis plant is inoperable
- Sanitary effluent is mixed with stormwater
- Building 374 evaporation capacity is inadequate

- Water balance is possible only if incoming water equals evaporation losses

These problems would be addressed by:

- Converting the existing potable water storage and delivery facilities to the industrial water use system
- Converting the existing raw water system to the potable system for shower and drinking purposes only
- Reinstating the reverse osmosis treatment capability

The advantages of this proposal included the following:

- No offsite discharge of sanitary/process water
- All available water loads connected
- Water loads would be serviceable with about 7000 linear feet of new exterior plumbing
- Changing internal water balances would be self-correcting
- Added evaporator capacity would be required
- Sanitary wastewater would be separated from stormwater
- Reduction in purchased/treated water
- Reduction in salts brought onsite in water supply
- Site water would be in balance without further changes
- Cross connections between potable and process water would be eliminated

3.2 Specific Non-Potable Water Use Potentials

Certain plant functions currently use potable/domestic water when water of lesser quality would suffice. These operations are described and quantified below:

Cooling Towers Many buildings at RFP, including 559, 771 and 865 are serviced by cooling towers that use domestic potable rather than raw water. For CY 89, this demand was approximately 11 MGY.

Air Washers Air washers at RFP are amenable to using raw water. In CY 89, approximately 12 MG of domestic potable water was used to service air washers.

Laundry For CY 89, the laundry facility in Building 778 used about 6.3 MG of domestic potable water. Raw water could suffice, but higher TDS and hardness in the raw water may affect latherablility and cleaning power. Additional testing is required to assess the water quality needs of the laundry.

Lawn Irrigation From plant utility records, lawn irrigation for CY 89 was approximately 1 MG.

Process Waters Plant industrial and laboratory processes use approximately 4 MGY in a wide variety of ways. Specific data on quality and quantity needs for each point of use needs to be determined.

Toilets and Urinals All sanitary facilities at the plant could use raw water for flushing, but this alternative would require installation of an extensive dual distribution system which is described later in this report. For CY 89, toilet and urinal usage was estimated to be 12 MG.

3.3 Wastewater Recycle Treatment Train

The preliminary structuring of a desired treatment train to accomplish the required wastewater treatment coupled with the STP upgrade proposed under Task 10 of the Zero Offsite Discharge Study is displayed in Figure 10. This treatment train (which will be refined further under Task 12, Reverse Osmosis/Mechanical Evaporation) recognizes the unique nature of the RFP liquid and solid waste streams including the following:

- Constraints identified in Task 10, Sanitary Treatment Plant Evaluation Study

- Treatment alternatives screening process presented in Task 10, Sanitary Treatment Plant Evaluation Study

- Past, present and future infiltration/inflow

- Cross connections between potable and process water systems

- Historical contaminants of concern, e.g. chromium, cyanides and toxic organics

- Toxic metals and radioactivity associated with both liquid and solid waste streams

- The potential for RFP expansion to 9,000 persons or conversely the contraction to 3,000 persons (from existing 6,000)

- The existing French drains and potential connection to the sanitary sewer (nitrates and organics)

- Questionable potable water use metering records

- Questionable process water use metering records

- Questionable wastewater metering records

Projections for production activities at RFP indicate that onsite employee levels could reach 9,000 persons plus outside consultants, vendors and visitors. On the other hand, employee levels could just as likely drop to 3,000 persons at some time during a 20-year planning horizon. At present, 1990, about 6,000 employees are onsite. In this context, the structuring of alternatives must accommodate wide swings in possible employee levels. Parallel treatment trains for all major unit operations/processes is recommended to properly address these variations. At 9,000 employees, a STP influent flow of about 0.4 MGD will result, at 3,000, 0.13 MGD. Parallel trains of 0.2 MGD can service the variations noted. A flow of 0.4 MGD (9,000 persons) is based on a current employment level of 6,000 persons and a flow of about 0.25 MGD.

In the structuring of this treatment train, it was taken as given that the system must be fool-proof, an effective water conservation program would be implemented, and that a multiple barrier approach would be required for all water/wastewater liquid/solid streams. Additionally, treatment during construction must be maintained at all times, and any treatment required beyond a certain quality level would be accomplished by point-of-use treatment for each specific process use. It is expected that construction of the noted improvements could be affected by Solid Waste Management Units (SWMU) either those of record or those determined in the future. Such construction would not impact any wetland areas. It may be desired to place the treatment features near Building 124 to reflect the RFP's commitment to reuse/recycle. This would assist both employees and guests in recognizing and implementing the total water resource management program at RFP. It may also minimize the effect of SWMU's on construction activities. The treatment facilities could also be located near the current STP.

3.3.1 Treatment Train Comparisons

The preceding desired treatment train and two additional treatment configurations were evaluated in the following context:

Wastewater Characterization

- Toxicity/bioassay; LC_{50} (mg/l)
- Flow; % of total
- Key physical, chemical, biological constituents
- Biodegradability, i.e.

  Toxic/Nondegradable? Toxic/Degradable?

  Nontoxic/Degradable? Nontoxic/Nondegradable?

Once classified, each process wastewater stream can be evaluated for process modification/elimination or compatibility with downstream facilities in place or for new facilities design.

Individual waste stream characterization at RFP has not been done. The RFP sanitary wastewater treatment facility has utilized a biological system, activated sludge, throughout the plant's operating history. This effectively is an in-situ toxicity test, even though all wastewaters are combined for treatment. Because the RFP is currently negotiating a new discharge permit, and because biomonitoring will probably be included in any new permit, it is well to remember this simple yet effective toxicity classification approach to individual process waste streams and how the RFP might address the toxicity issue.

Balanced against the desired treatment train developed in the preceding section is a comparison of two options to this train or system in general. The Denver Water Board, after more than ten years of pilot testing and two years of evaluating demonstration processes, selected the following treatment train:

- Biological nitrification (denitrification may be provided)

- High pH lime treatment
- Recarbonation
- Filtration
- Ultraviolet irradiation disinfection
- Activated carbon adsorption
- Reverse osmosis
- Air stripping
- Ozonation
- Chloramination

This train "incorporates the multiple barrier concept providing reliability and removal capabilities unprecedented in conventional water treatment plants." The redundancy/multiple barrier components reflect the end-use of the treated product and the attendant liabilities therewith, i.e. potable water reuse (Denver Water Board,1983).

Similar product water quality is obtainable solely from the demineralization of sand-filtered secondary effluent by reverse osmosis (EPA, 1987). The County Sanitation Districts of Los Angeles County reported on their work conducted in 1973. L.A. County's work was not oriented to potable reuse but instead for reuse by large industrial customers. Table 1 compares selected water quality data for each of the Denver Metro and L.A. County experiences.

The significance of these comparative results is the lack of necessity for further treatment of secondary effluent beyond conventional filtration, when followed by reverse osmosis or similar membrane separation facilities. This is particularly true for a non-potable reuse scenario, as at RFP. This conclusion was supported in a 1982 study wherein 14 physical-chemical operations/processes, singularly or in combination, were evaluated for an ability to remove dissolved organic carbon from a secondary wastewater effluent. The largest organic removals were obtained with reverse osmosis and, significantly, the use of activated carbon (either before or after reverse osmosis) was unnecessary (Dewalle, 1982).

TABLE 2

AVERAGE WATER QUALITY CHARACTERISTICS
L.A. COUNTY SANITATION DISTRICT; (DENVER WATER BOARD)

ANALYSIS	FEED (mg/1)	PRODUCT (mg/1)
Na	175.0 (117.0)	13.8 (7.3)
K	21.9 (10.0)	1.4 (0.5)
Ca	103.9 (57.0)	0.94 (*)
Mg	21.8 (12.0)	0.34 (*)
Cl	155.4 (83.0)	18.9 (18.0)
SO_4	534.0 (156.0)	4.9 (1.0)
PO_4-P	19.8 (5.3)	0.26 (2.4)
NH_3-N	33.1 (19.0)	1.8 (0.1)
NO_3-N	0.10 (0.2)	0.07 (.06)
TCOD	57.1 (17.4)	0.95 (0.2)
TDS	1,127 (585)	52 (22)
Turbidity (JTU)	3.3 (7.4)	0.03 (.05)
Gross Alpha	-- (3.6)	-- (*)
Gross Beta	-- (6.5)	-- (*)

* Below Detection Limit

4.0 STORAGE AND DISTRIBUTION ALTERNATIVES

Figures 2 and 3 noted earlier described the RFP existing potable and raw water treatment, distribution and storage features. In addition to a selected reuse treatment scheme, pumping, storage and distribution alternatives for both potable and non-potable facilities must be structured. Specific reuse opportunities to further replace potable water with treated wastewater were described in 3.2.

4.1 Alternative 1 - Nonpotable Reuse

Reuse effluent (through and including ultrafiltration/reverse osmosis) would be conveyed in the nonpotable industrial loop via a constant pressure variable volume pump equipped with standby power as shown in Figure 11. Piping additions to large reuse locations would be extended from the existing industrial water loop only. A schematic of Alternative 1 is given in Figure 11, with a plot plan of the distribution network given in Figure 12.

The existing potable domestic water loop would remain unchanged including the 300,000 gallon elevated tank and fire protection system. For Alternative 1, additional raw water lines would be extended to convert the air washers in the 400 and 800 series buildings, Building 771, as well as the 712/713 cooling towers, the laundry facilities in Buildings 556 and 778 and the cooling towers for Buildings 559, 771, 881, 883 and 865. Two methods exist for the routing of the treated sanitary effluent into the extended raw water system. One method would pump the treated effluent from Building 995 to a point near the RFP west entrance. The STP effluent treatment facility would be located near the RFP west entrance for high public visibility. Another method would be to site the treatment facility near Building 995 and to route the treated STP effluent up Central avenue. This method would be the most cost effective as it requires the least amount of pipe. The additional lines required as well as the two methods of effluent routing are given in Figures 11 and 12. A water balance for CY 89, had Alternative No. 1 been implemented, is presented on Figure 13.

4.2 Alternative 2 - Potable/Nonpotable System Switch

In order to facilitate the reuse proposal suggested by Rose (1990), all potable domestic drinking, shower and food processing facilities would be disconnected from the existing potable system and reconnected to the existing nonpotable raw water line. The existing raw water line would then be connected to the existing water treatment facility and a new constant pressure/variable volume pumping system would be constructed to maintain system pressure (See Figure 14). Conversely, the existing potable domestic water system would receive treated wastewater effluent inputs. The existing 300,000 gallon elevated storage tank and fire protection system would remain connected as at present and would serve to receive reuse effluent prior to use/recycle for individual plant processes. The existing domestic potable distribution network would be extended to additional points of use shown on Figure 15. A water balance for CY 89 had Alternative 2 been implemented is given in Figure 16.

It is assumed that the following installation/construction sequence would be followed to accomplish the switch described:

1. Install, but not connect, all required new piping to drinking fountains, sinks, showers and food processing equipment which will be added to the "new" potable system.

2. Convert existing raw water system to quality standards suitable to transport potable water.

3. After testing demonstrated safety of "old" raw water system, connect sinks, showers and food processing facilities to "old" raw water system which is now the new potable system.

4. Connect discharge lines from Building 374 evaporator and the new effluent treatment facility to the former domestic cold water system which is now the current recycle system for non-potable water.

It should be noted that normal operation of the reuse system would be based on the 300,000 gallon elevated tank water level. The 500,000 gallon ground level tank would be filled with non-potable water via the elevated tank or potable water from the water treatment plant. Its contents would only be utilized if the effluent reuse volume cannot maintain the elevated tank water level under normal use conditions or during a peak demand such as fire. Should the RFP desire, the new nonpotable reuse loop could be used as a heat source (winter) or heat sink (summer) with the use of local, water to air heat pumps. Any particular building(s) with heating and cooling needs could use the water to displace electrically driven/fired equipment if the economics were favorable. Assuming a delta T of 10°F and 400,000 GPD effluent flow, about 1,400,000 Btu/hr could be made available. This is equivalent to about 350 H.P. This heat source/sink is also possible under Alternative 1.

4.3 Alternative 3 - Potable Reuse

Alternative 3 assumes that effluent from the reuse treatment train (through and including ultrafiltration and reverse osmosis) would be stored and returned to the raw water facilities feeding Building 124, the domestic potable water treatment plant. The CY 89 water balance shown in Figure 6 indicates that 74 MG of effluent could be returned as raw water input to Building 124. At this point 49 MG would go for industrial use leaving a balance of 25 MG. This 25 MG would be blended with 47 MG from raw water storage (about 3:1 dilution ratio) and conveyed for treatment to Building 124. Ozone treatment would precede the plant's existing coagulation, flocculation and sedimentation facilities. Also, ozone treatment would occur just prior to the existing multi-media filtration (following coagulation, flocculation, sedimentation). No changes would be made to the existing industrial non-potable and domestic potable storage and distribution facilities. This alternative is effectively direct potable reuse at a 3:1 initial dilution (raw water to reuse water). At present there are no known direct reuse systems in service in the U.S. Many indirect i.e., wastewater effluent discharge to a water course, extraction for treatment and potable use, systems are in existence. The County Sanitation Districts of L.A. County completed in a 1984 a five year groundwater basin recharge project using wastewater (Los Angeles County, 1984). The subsequent extraction and potable use of the groundwater did not demonstrate any measurable adverse impacts on the population ingesting the water. The health impacts of reuse have been the single largest constraint on water reuse projects of this type, regardless of location. A preliminary schematic is given in Figure 17. A water balance for CY 89 had Alternative 3 been implemented is given in Figure 18.

4.4 Recommended Alternative

An alternative evaluation matrix utilizing eleven evaluation criteria and weighting factors follows. General descriptive comments relative to each factor and score follow the matrix. As noted, the recommended alternative is Alternative 1. Within the alternative evaluation system are weighting factors that influence the overall zero-discharge study. These factors were selected by a committee consisting of cognizant DOE and EG&G personnel. The matrix used to evaluate and weigh Alternatives 1 and 2 is given in Table 3. Shaded areas on Table 3 denote areas of concern. General descriptive comments pertinent to each factor and score follow the matrix.

<u>Storage and Distribution Alternatives</u>

Note: All ratings assume implementation of the recommended alternative from Task 10 followed by additional treatment i.e., ultrafiltration plus reverse osmosis for system salt control.

- <u>Controlled Discharge</u> - each alternative utilizes secondary effluent upgraded with treatment noted above. With suitable plumbing, each of the three alternatives can be equipped to either allow or prevent controlled discharge to each of the site's A, B and C drainages.

- <u>Waste Generation</u> - as noted, waste generation from treatment is the same for all alternatives; no waste generation is associated with the storage and distribution functions.

Table 3

EVALUATION MATRIX

TASK 11&13

EVALUATION FACTORS	WEIGHTING FACTOR	ALT 1 (Alternative 1)		ALT 2 (Alternative 2)		ALT 3 (Alternative 3)	
		S	W	S	W	S	W
CONTROLLED DISCHARGE	10	5	50	5	50	5	50
WASTE GENERATION	7	4	28	5	35	5	35
RISKS	8	5	40	4	32	3	24
COST	6	5	30	1	6	1	6
DESIGN AND CONSTRUCTION SCHEDULE	6	4	24	2	12	1	6
FLEXIBILITY	8	4	32	5	40	5	40
WATER RIGHTS	5	4	20	4	20	4	20
AIR EMISSIONS	10	5	50	5	50	5	50
WETLANDS/T&E SPECIES	10	5	50	5	50	5	50
IHSS (SWMU)	10	5	50	4	40	5	50
PUBLIC ACCEPTABILITY	8	5	40	5	40	1	8
TOTALS			414		375		399
RANK			1		3		2

S = SCORE; W = WEIGHTED SCORE = SCORE x WEIGHTING FACTOR

- Risk - Alternative 1 represents a risk avoidance advantage. This is because Alternative 2 must switch current potable lines to non-potable and vice versa. Alternative 3 represents total potable reuse of treated effluent. While The risks of such potable reuse have been lessened considerably with current treatment methodology, user perceptions are not, and will not be, unanimous in the implementation of potable reuse.

- Cost - Alternative 1 represents a distinct cost advantage because existing potable and non-potable delivery systems remain as is, with the exception that the non-potable delivery system would be served by a constant pressure variable volume pump. The existing fire delivery system would remain as is.

  The non-potable delivery system would be served by constant pressure variable volume pumps. These two pumping units would require standby power or continuous running power to assure delivery of normal domestic and fire flows. Without such power, significantly higher risk would be assumed; this condition exists for all alternatives. Alternative 3 also requires additional treatment (ozone pretreatment) capability in conjunction with the existing water treatment plant.

- Design and Construction Schedule - The distribution system of Alternative 1 would be the simplest and quickest to construct. Alternative 1 would also require minimal amounts of indoor plumbing relative to Alternative 2. No significant differences between Alternatives 1 and 3 are apparent regarding design/construction schedule.

- Flexibility - Alternatives 2 and 3 are the most flexible alternative in that the water balance is self-correcting, i.e. new loads that could use non-potable water would be serviced by their effluent. Alternative 3 must receive water inputs treated via the existing water plant, upgraded with ozonation.

- Water Rights - All alternatives represent the same perspective regarding water rights. Because this issue was not addressed fully in Tasks 10 or 11/13, some reservation should be acknowledged, thus an equal rating of 4 for each alternative.

- Air Emissions - none of three alternatives represent any apparent advantage with regard to emissions. Short term construction emissions would be equal in each case.

- Wetland/T & E - none of these three alternatives have any discernible impacts in this regard.

- IHSS/SWMU - None of the three alternatives have any known impacts at this time. There may be some advantage to siting the U.F./R.O. treatment and storage facilities near the RFP entrance in lieu of at the WWTP. This would not impact the storage/distribution alternatives, however

- Public Acceptability - Alternative 1 represents a straight-forward implementation program. Alternatives 2 and 3 have serious public health concerns/constraints not easily overcome, if at all.

The preliminary process schematic for treatment/reuse of sanitary wastewater is shown in Figure 10. Features of the schematic are explained in the following text.

Items 4.4.1 through 4.4.9 are those features described under Task 10, Recommended Alternative.

Items 4.4.10 through 4.4.14 provides a preliminary description of those additional treatment steps required to reach a reuse/recycle water quality suitable for reuse at RFP.

4.4.1 Flow Metering

Essential to any water wastewater system is the collection of flow data. The design of treatment facilities, operational monitoring and discharge permit monitoring requires knowledge of flow rates, flow variability and total flow. In this instance an open-flow system utilizing a flume primary sensor with indicator - totalizer - recorder is essential (NEW). This system must precede any downstream facilities to accurately reflect actual flow characteristics and must meter all wastewater to be treated.

4.4.2 Powdered Activated Carbon

The addition of powdered activated carbon (NEW) is noted at selected locations for the purposes of adsorbing soluble organic material and oxygen and to aid in the subsequent clarification/flotation/filtration process. Carbon is removed with other waste activated sludge materials. Carbon is able to address high BOD/COD removals, hydraulic and organic overloads, solids sedimentation, a high degree of nitrification/denitrification, phosphorus reduction, heavy metal, dyes and other toxic reductions, and adsorbing detergents of various descriptions.

4.4.3 Flow Equalization

Flow equalization (EXISTING) provides for increased efficiency, reliability and control for downstream physical, biological and chemical processes. This is accomplished by dampening both flow and mass loading variations. Ideally, a constant flow and constant mass loading result in better process control and effluent quality. Significant flow and mass loading variations exist at RFP due to the diversity of wastewater flow sources and the makeup thereof.

4.4.4 Grinding

The utilization of a muffin monster grinder (NEW) prior to activated sludge represents historical use of such grinding equipment at RFP. Ground materials are passed to downstream activated sludge tankage (parallel units) for periodic removal from the system. Such materials would be wasted as part of the overall waste sludge mass.

4.4.5 Activated Sludge

Activated sludge is the current method of treatment at RFP prior to filtration, disinfection and discharge. Use of the facility has been limited to reduction of carbonaceous BOD_5, although the existing plant is capable of nitrification at current hydraulic and organic loadings. Indications are that nitrogenous BOD_5 reduction, such as nitrification (NH_{4+} ->NO_3) will be a future permit condition as will denitrification (NO_{3-} -> N_2^). Nitrification-denitrification effectively addresses the potential toxicity of unionized ammonia (NH_4+) to local biological communities and the potential toxicity of nitrate (NO_3-) to downstream users relying on the water resource for raw water supplies and subsequent potable water delivery. The activated sludge process (and a multitude of system variants developed over the last 100 years) for treatment wastewater of extremely divergent origins is a testament to its overall capabilities and robustness. One relatively recent variant of the process is sequencing batch reactor (SBR) technology. This particular technology is a fill-and-draw activated sludge process developed about 1920. Its use takes advantage of the following:

- Serves as additional equalization volume
- Activated sludge can not be "washed out" with hydraulic surges e.g., backwash water volumes
- Can be operated to achieve nitrification-denitrification or phosphorus removal

For the RFP facility (NEW) activated sludge tankage would be plumbed to allow fill-and-draw operation (SBR) or continuous flow operation as currently operated. Parallel trains would be provided to ensure continuous operation. Waste activated sludge solids (including grindings) would be wasted to a belt press to reduce sludge water content. Press filtrate would be returned to the head of the plant and dewatered solids dried by gas-fired dryer.

4.4.6 Effluent Storage

A 1.0 MG storage facility (NEW) would provide for about 2.5 days of storage at a flow of 0.4 MGD. This would serve to receive effluent flow from the activated sludge system prior to flotation/ filtration (NEW) or clarification and pressure filtration (EXISTING).

Note: Operation in the fill and draw flow mode would be: activated sludge, storage, disinfection, flotation/filtration and discharge or reuse. Operation in the continuous flow mode would be activated sludge flotation/filtration (or clarification/filtration) and discharge. Should the new RFP permit allow continuous discharge to South Walnut Creek, the flotation/filtration or clarification/filtration step may (as a function of the final permit) most likely be preceded by ozone disinfection. Ozone has been shown to be effective in metal and color removal, organics oxidation, taste and odor removal and other similar positive effects when used in combination with downstream filtration. Because of the zero discharge nature of this study, reuse is the flow route to be utilized and, therefore, the use of ozone would not be warranted.

4.4.7 Disinfection/Organics Fractionation

Following storage of activated sludge effluent, the flow stream (constant flow) would be disinfected with methylene blue enhanced ultraviolet light (NEW). Methylene blue (and other dyes) is widely used as a photosensitizer due to its effectiveness, low cost, ready availability, ease of removal via adsorption and penetrability into high turbidity wastewater. Its effectiveness is in combination with visible light at 670 nm. Ultraviolet irradiation between 200 and 300-350 nm is active in similar photochemical reactions with microorganisms and organics. When used in combination, disinfection is accomplished as is the photochemical destruction of a broad range of organics, such as herbicides and insecticides. The addition of powdered carbon following disinfection facilitates the adsorption of methylene blue and fractionated organics for subsequent removal via flotation/filtration or clarification/filtration. The use of light enhanced disinfection is for protection of downstream reuse treatment facilities that rely on membrane separation of contaminants. It is questionable whether disinfection per se is required for control of membrane biofouling.

4.4.8 Flotation/Filtration

Flotation/filtration (NEW) separation of activated sludge and other water/wastewater system contaminants is an accepted and well documented unit operation. The use of dissolved air flotation to separate solids of varying origin from a water source, followed by filtration, effectively removes those solids of concern to both water and wastewater regulatory officials. Similarly, clarification/filtration (EXISTING) is effective in addressing solids removal in a conventional manner. Each of these unit operations utilizes conventional coagulants such as alum and polymer.

4.4.9 Discharge Point

The option to discharge to South Walnut Creek is a desirable aspect of any reuse/zero discharge program at RFP. Whether this option will be allowed in current permit renewal negotiations is unknown. As noted in 4.4.6 above, continuous discharge could include provisions for ozone disinfection prior to flotation/filtration or clarification/filtration.

4.4.10 Ultrafiltration

This feature represents the major reuse/zero discharge aspect of the RFP project. Wastewater subjected to physical (flow equalization/grinding), biological (activated sludge) and chemical (powdered carbon, alum, polymer additives) treatment would be followed by disinfection/fractionation and then membrane separation of residual contaminants via ultrafiltration (NEW). The term ultrafiltration is meant to include cross-flow/micro/nano/ultrafiltration as general terminology for membrane technology that rejects most contaminants in liquid streams, short of ionized cations/anions (dissolved salts). The selection of a specific membrane type, material, operating pressure, configuration and others, would be based on a rigorous examination of preceding treatment and product water use requirements. In the context of this study, treatment via ultrafiltration is the highest level of treatment required for all reuse applications at RFP short of potable reuse. Conventional disinfection would follow the ultrafiltration step. The ultrafiltration system would consist of 2 parallel 150 gpm modules (0.4 MGD). Rejects from the system would be returned to the sanitary sewer.

4.4.11 Reverse Osmosis

Following ultrafiltration pretreatment for reuse, a parallel reverse osmosis system (NEW), operating on a batch basis, would remove dissolved salts from the reuse stream when salt levels increase to 300 mg/l or greater. The reverse osmosis system (2 in parallel @ 75 gpm each or 200,00 gpd) would remove salts to a rejection level of about 95 percent, with blending of the reverse osmosis and ultrafiltration streams to achieve system dissolved salt levels near 150 mg/l. The selection of specific membrane type, configuration, operating pressure and others would be made based on further detailed product water and brine stream characterization. Reverse osmosis brines would be conveyed to a waste stream concentration step described in 4.4.12 below.

4.4.12 Vapor Compression Evaporation

Reject streams from the reverse osmosis process would be conveyed to a vapor compression evaporation (NEW) system for further concentration. Vapor compression evaporation recovers the latent heat from evaporated vapor, rather than rejecting this heat. The recovery is accomplished by using mechanical compression to increase the pressure and temperature of the evaporated vapor and by returning the high pressure/temperature vapor to the evaporator where it condenses and gives up its latent heat, evaporating additional water. The vapor compression unit discharge would go to a crystallizer for further concentration and waste minimization.

The most attractive feature of vapor compression evaporation over competing systems is significantly lower energy consumption and operation costs. It is recommended that this system be utilized in conjunction with item 4.4.14 to be described below.

4.4.13 Reuse/Discharge

Item 4.4.9 described the desirability of retaining discharge as an effluent handling option. Whether this would be for the total effluent stream (0% reuse) or none of the effluent (100% reuse) is immaterial. The option is the critical issue. Assuming an emphasis on reuse, effluent treated in the sequence shown would allow 100% reuse at a salt level of about 150 mg/l. Similarly, use of the total sequence would allow discharge of a 150 mg/l salt effluent or, if discharged prior to reverse osmosis treatment, a discharge of 300 mg/l salt.

4.4.14 Continuous Duty Generator

A continuous-running 4-cycle natural gas powered engine (NEW) would be installed to serve the purposes of what would typically be a standby power generation system for selected treatment plant electrical equipment. In addition to reducing electrical costs (operating and demand charges), the unit would recover waste heat to serve a variety of potential uses including ultrafiltration/reverse osmosis influent heating and makeup steam for the vapor compression evaporation system.

One of the more popular heat recovery systems in use today for reciprocating engines employs the principle of ebullient cooling. The ebullient system has gained its popularity largely because of its simplicity, low operating and maintenance cost, and its capability to produce steam at pressures suitable for subsequent uses (12-15 psig). The ebullient system utilizes the heat of vaporization to remove rejected heat from the engine. Steam, as such, is not allowed to collect within the engine but is moved through the water passages, along with the high temperature water by thermal action, to a steam separator located at an elevation somewhat above that of the engine. Low pressure steam from this unit would be upgraded by the vapor compression system described in 4.4.12 above.

5.0 COST ESTIMATES/IMPLEMENTATION SCHEDULE

5.1 Costs

All of the cost figures used in this report are order of magnitude cost estimates only and should be considered accordingly. Where appropriate, Facilities Engineering Manual 009 was consulted for specific procedures, format and adjustments. Detailed construction cost estimates were beyond the scope of this study. Capital costs have been emphasized, but significant operation and maintenance (O and M) costs were addressed when appropriate. No amortization schedule i.e., interest rates, payback periods were used in these analyses.

5.1.1 Pipelines and Tanks

The cost estimating group of EG&G's Facilities Engineering Department provided the following installed unit costs:

- Four to ten inch ductile iron pipe with one valve, excavation, fill and materials on Plant site.	$80-100 per foot
- Steel tank on concrete pad, piping and pump, non-hazardous waste, no RCRA berms.	$ 0.34 per gallon
- Open ponds with membrane, non-RCRA, 10 feet depth	$0.04 per gallon

5.1.2 Treatment Facilities and Pump Station Estimates

When possible, specific vendor quotes were obtained. These were then compared against EPA cost curves for both capital, operation and maintenance costs. Adjustment of all costs was then made to reflect construction at RFP.

5.1.3 Preliminary Opinion of Probable Cost

A preliminary construction cost estimate for the recommended alternative (Alternative 1) is presented below:

ITEM	ELEMENT OF COST	COST
1	Pump Station - #995 to #124	$ 75,000
2	12,800 L.F. 8" Force Main @ $100/Ft.	$1,280,000
3	Raw Water Line Extensions, 3,150 L.F. @ $100/Ft.	$ 315,000
(Alternative 1 Cost)	Subtotal	$1,670,000[1]
4	U.F./R.O. and V.C.E. Equipment @ .4 MGD	$1,500,000
5	6,000,000 gallon (6.0 MG) Storage (Product Water)	$ 300,000
6	Product Water Pump	$ 50,000
7	Bldg. to House UF/RO/VCE (100' x 100' x $50/FT^2)	$ 500,000
8	Misc. Piping/Valves/Modifications	$ 100,000
9	Site Work; Paving, Drainage, Piping	$ 250,000
10	Miscellaneous/Chem Feed Systems (2)	$ 50,000
11	Electrical (15%)	$ 880,000
12	Mechanical (10%)	$ 600,000
	Subtotal	$4,230,000[2]
	TOTAL	$5,900,000[3]

1 The pump station would deliver effluent from the RFP STP to a point near Bldg. 124, the RFP WTP, via 12,800 lineal feet of 8 inch pipe.

2 More detailed examination of Reverse Osmosis/Mechanical Evaporation costs to be included in Task 12 Study.

3 Cost does not include engineering, construction management, land, contingencies, legal/admin.

6.0 CONSERVATION

Brief mention was made earlier of the need for an aggressive water conservation effort at RFP. The successes of these efforts have been well documented, are cost effective and should precede any eventual reuse/recycle efforts at the plant. These measures include process water recycle (Task 11 - Process Water Reuse Potential), water leak surveys, extensive metering and meter maintenance, low flow shower heads and toilets, and, paralleling these physical accomplishments, a plant-wide water conservation education effort. A more detailed listing of water conservation considerations and opportunities is described in Reference No. 2.

7.0 OTHER CONSIDERATIONS

Each of the treatment, storage, distribution, reuse, recycle and conservation efforts described in this report assume consistency with all State of Colorado water rights law. Because of native/non-native water rights considerations in the State, a complete review of the recommended system in this context is required.

The selected treatment train (Figure 10) and associated descriptive writeups noted the need for a continuous running electrical generator. The generator would supply electricity for all wastewater pumping and treatment needs and would have waste heat available as well. The waste heat could be recovered as low pressure steam or hot water and could be used as follows:

1. Heat source for raising activated sludge operating temperature. Alternatively, heat source to raise effluent temperature for optimum ultrafiltration (U.F.)/reverse osmosis (R.O.) treatment.
2. Heat source, hot water or low pressure steam, for drying waste activated sludge.
3. Heat source as low pressure steam for makeup to the vapor compression evaporator.
4. Local heat source (Bldg 995) for water-to-water or water-to-air heat pump system.

Continuous running generators are much more flexible than standby generator units and can serve to significantly reduce both electrical demand and service charges. Specific cost savings could be determined only after completion of a comprehensive energy audit conducted during preliminary design.

8.0 GLOSSARY

Absorption: Assimilation of molecules or other substances into the physical structure of a liquid or solid without chemical reaction.

Activated Sludge: An aerobic biological process for conversion of soluble organic matter to solid biomass, removable by gravity or filtration.

Activated Sludge Treatment: A biological treatment process in which sewage is aerated and agitated with a high concentration of flocculated bacteria and then clarified by sedimentation.

Adsorption: Physical adhesion of molecules or colloids to the surfaces of solids without chemical reaction.

Aeration: Causing intimate contact between liquid and air to dissolve oxygen in the liquid accomplished by diffusing air bubbles into the liquid.

Aerobic Organism: An organism that requires oxygen for its respiration.

Aerobic Treatment: A biological treatment process in which bacteria stabilize organic material in the presence of dissolved oxygen.

Alkalinity: By definition, total alkalinity (also called M alkalinity) is that which will react with acid as the pH of the sample is reduced to the methyl orange endpoint - about pH 4.2. Another significant expression is P alkalinity, which exists above pH 8.2 and is that which reacts with acid as the pH of the sample is reduced to 8.2.

Anaerobic Organism: An organism that thrives in the absence of oxygen.

Anaerobic Treatment: A biological treatment process in which bacteria stabilize organic material in the absence of dissolved oxygen.

Anion: A negatively charged ion resulting from dissociation of salts, acids, or alkalies in aqueous solution

Bacteria: Microscopic single-cell organisms typically identified by their shapes: coccus, spherical; bacillus, rod-shaped; spirillum, curved, etc.

Biocide: A chemical used to control the population of troublesome organisms.

Blowdown: The withdrawal of water from an evaporating water system to maintain a solids balance within specified limits of concentration of those solids.

BOD: Biochemical oxygen demand of a water, being the oxygen required by bacteria for oxidation of the soluble organic matter under controlled test conditions.

Btu: British thermal unit

Buffer: A substance in solution which accepts hydrogen ions or hydroxyl ions added to the solution as acids or alkalies, minimizing a change in pH.

C: Centigrade degrees
Cake: A term applied to a dewatered residue from a belt filter press, centrifuge, or other dewatering device.

Cation: A positively charged ion resulting from dissociation of molecules in solution.

Centrate: The liquid remaining after removal of solids as a cake in a centrifuge.

cfm: cubic foot per minute.

cfs: cubic foot per second.

Chlorination: The application of chlorine, generally to treated sewage, to kill microorganisms that are discharged from the treatment plant with the treated sewage.

Coagulation: The neutralization of the charges on colloidal matter (sometimes considered jointly with flocculation).

COD: Chemical oxygen demand, a measure of organic matter and other reducing substances in water.

Coliform Bacteria: Bacteria found in the intestinal tract of warm-blooded animals and used as indicators of pollution if found in water.

Concentration: The process of increasing the dissolved solids per unit volume of solution, usually by evaporation of the liquid; also, the amount of material dissolved in a unit volume of solution.

Condensate: Water obtained by evaporation and subsequent condensation.

Contaminant: Any foreign component present in another substance; e.g., anything in water that is not H_2O is a contaminant.

Demineralization: Any process used to remove (salt) minerals from water.

Denitrification: In the absence of dissolved oxygen, bacterial breakdown of nitrates to nitrogen gas and oxygen. The oxygen is used by bacteria and the nitrogen gas is released to the atmosphere.

Desalination: The removal of inorganic dissolved solids (salt) from water.

Desalting: The removal of salt.

Dewater: To separate water from sludge to produce a cake that can be handled as a solid.

Disinfection: Application of energy or chemical to kill pathogenic organisms.

D.O.: Dissolved oxygen.

Effluent: The treated and clarified sewage that flows out of the treatment plant.

Equalization: Minimization of variations in flow and mass composition by means of storage.

F: Fahrenheit degrees

Facultative Organisms: Microbes capable of adapting to either aerobic or anaerobic environments.

Filtrate: The liquid remaining after removal of solids as a cake.

Filtration: The process of separating solids from a liquid by means of a porous substance through which only the liquid passes.

Flocculation: The process of agglomerating coagulated particles into settleable floc, usually of a gelatinous nature.

Flotation: A process of separating solids from water by developing a froth in a vessel in such fashion that the solids attach to air bubbles and float to the surface for collection.

F/M ratio: Food-to-mass or food-to-microorganism ratio used to predict the phase of growth being experienced by the major microbial populations in a biological treatment process, such as activated sludge.

gal: gallon

gpcd: gallons per capita per day

gpd: gallon per day

gpm: gallon per minute

hp: horsepower

Infiltration: Leakage of groundwater into sewage piping.

Influent: The untreated sewage that flows into the treatment plant.

kw: kilowatt

lb: pound

Membrane: A barrier, usually thin, that permits the passage only of particles up to a certain size or of special nature.

Metabolize: To convert food, such as soluble organic matter, to cellular matter and gaseous by-products by a biological process.

Microorganism: Organisms (microbes) observable only through a microscope; larger, visible types are called *macroorganisms*.

mg: million gallons, also milligram

mgd: million gallons per day

ml: milliliter

Milligrams Per Liter (mg/l): The same as parts per million (ppm). An expression of the concentration of a specified component in water. A ratio of grams per million grams, pounds per million pounds, etc.

mg: microgram

Mixed Liquor: The contents of the aeration compartment of an activated sludge treatment plant. A suspension of sewage solids and microorganisms.

Neutralization: Most commonly, a chemical reaction that produces a resulting environment that is neither acidic nor alkaline. Also, the addition of a scavenger chemical to an aqueous system in excess concentration to eliminate a corrosive factor, such as dissolved oxygen.

Nitrification: A biological process in which certain groups of bacteria, in the presence of dissolved oxygen, convert the excess ammonia (NH_3) nitrogen in sewage to the more stable nitrate (NO_3) form.

NPDES permit: The National Pollution Discharge Elimination System permit required by and issued by EPA.

Osmosis: The passage of water through a permeable membrane separating two solutions of different concentrations; the water passes into the more concentrated solution.

Oxidation: A chemical reaction in which an element or ion is increased in positive valence, losing electrons to an oxidizing agent.

Pathogens: Disease-producing microbes.

Permeability: The ability of a body to pass a fluid under pressure.

pH: A means of expressing hydrogen ion concentration in terms of the powers of 10; the negative logarithm of the hydrogen ion concentration.

Pollutant: A contaminant at a concentration high enough to endanger the aquatic environment or the public health.

Polymer: A chain of organic molecules produced by the joining of primary units called *monomers*.

ppb: part per billion

ppm: part per million

Precipitate: An insoluble reaction product; in an aqueous chemical reaction, usually a crystalline compound that grows in size to become settleable.

Primary Treatment: A physical process, usually plain sedimentation, used to obtain partial treatment of sewage.

psi: pound per square inch.

Reverse Osmosis: A process that reverses (by the application of pressure) the flow of water in the natural process of osmosis so that it passes from the more concentrated to the more dilute solution.

SBR: Sequencing Batch Reactor; one of many variations of the activated sludge wastewater treatment process.

Scale: The precipitate that forms on surfaces in contact with water as the result of a physical or chemical change.

Secondary Treatment: A biological treatment process designed to achieve a high degree of sewage stabilization generally through the action of aerobic bacteria. e.g. activated sludge.

Sedimentation: Gravitational settling of solid particles in a liquid system.

Sewage: Waste fluid in a sewer; water supply fouled by various uses through the addition of organic and inorganic material.

Sludge Volume Index: An inverse measure of sludge density.

Softening: The removal of hardness (calcium and magnesium) from water.

Stoichiometric: The ratio of chemical substances reacting in water that corresponds to their combining weights in a theoretical chemical reaction.

Supernate: The liquid overlying the sludge layer in a sedimentation /digestion vessel.

Weir: A spillover device used to measure or control water flow.

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10.0 ACKNOWLEDGMENTS

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E.W. Mende, EG&G - ER/CWAD
A.C. Shah, DOE - E&G
J. McKeown, EG&G - FE/PSCE
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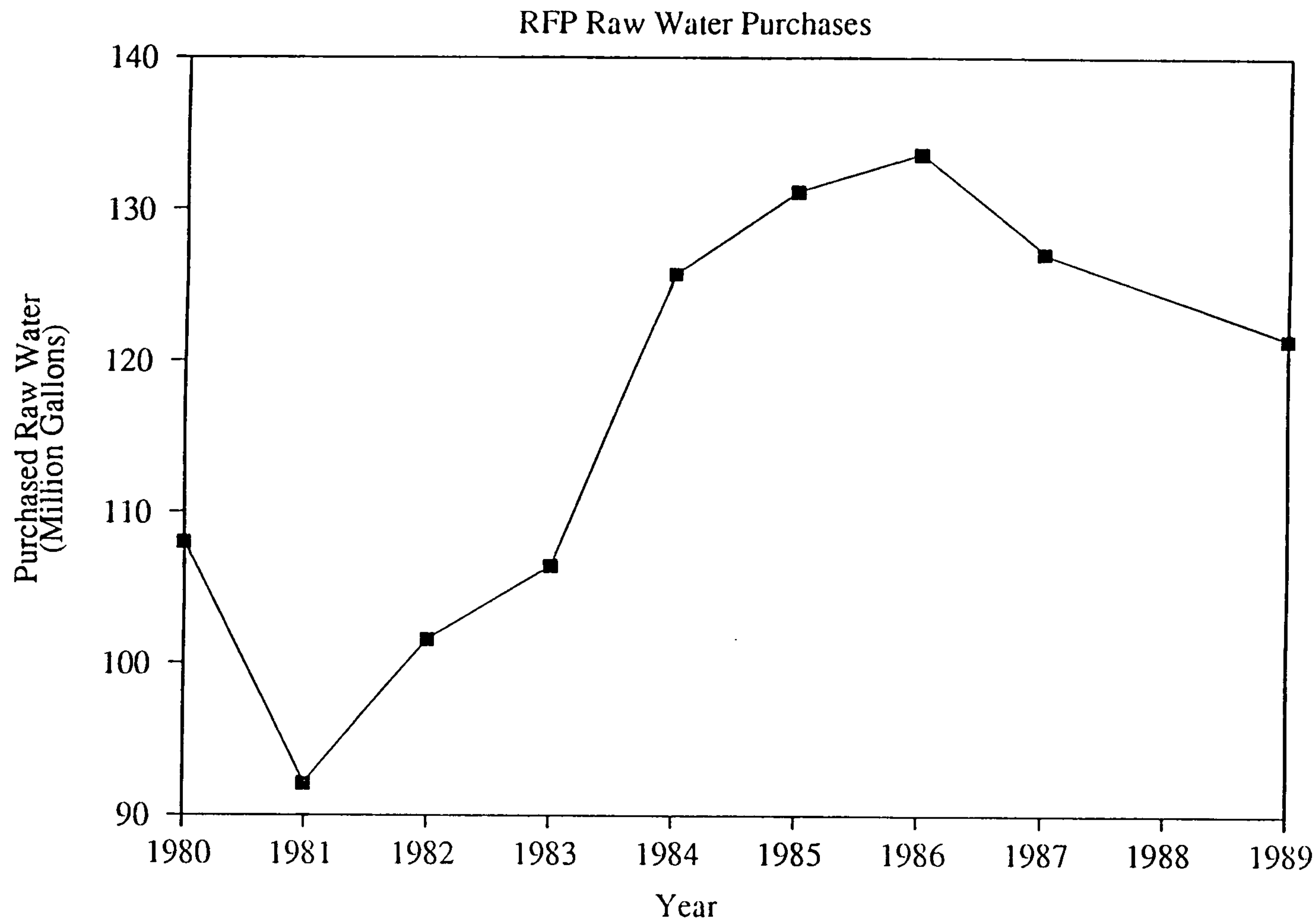
J. Ciucci, EG&G - RCRA/ER
C. Rose, CWAD consultant
R. Hillier, DOE-IH

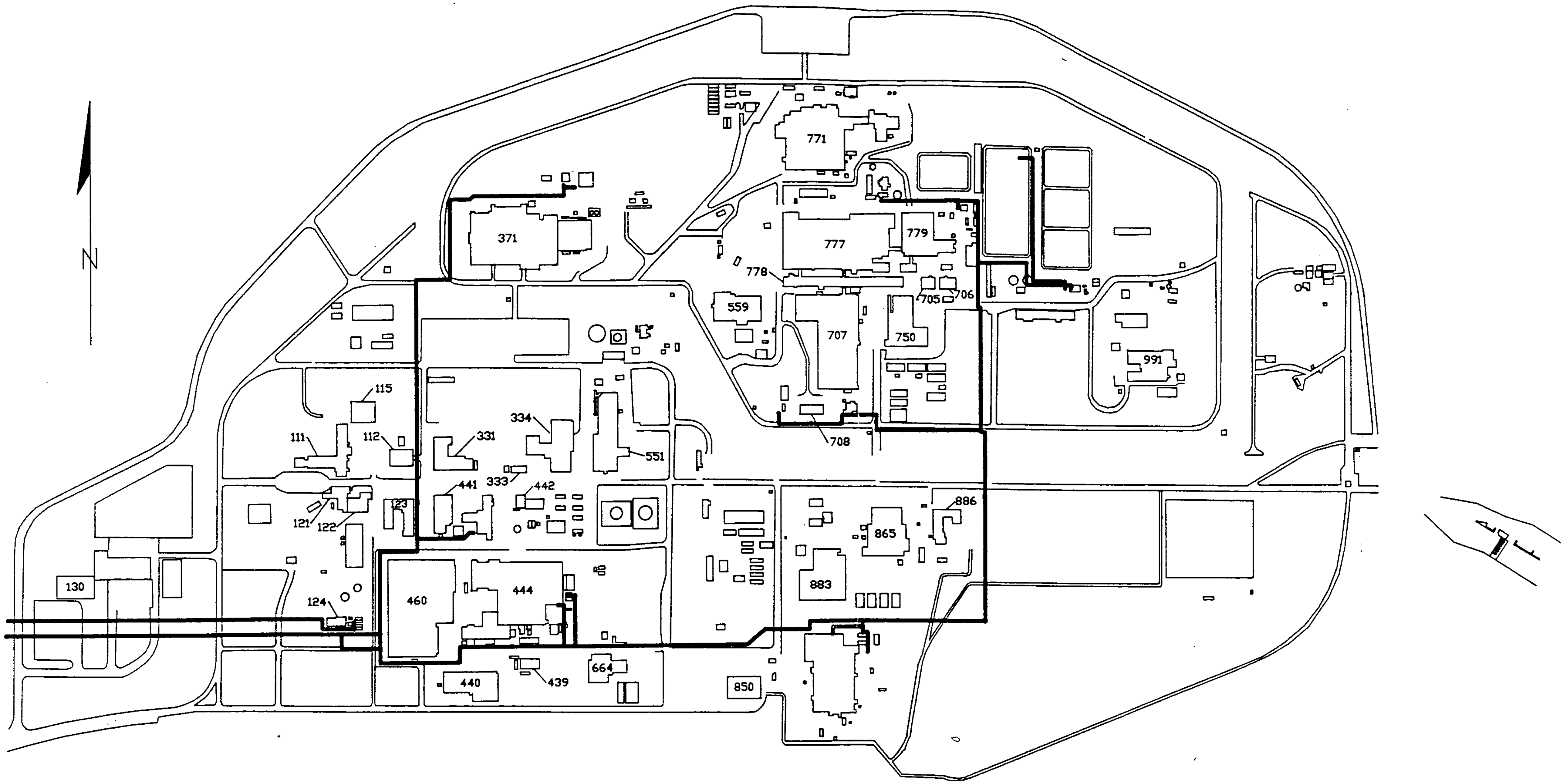
This report was prepared and submitted in partial fulfillment of the Zero-Offsite Water-Discharge Study being conducted by ASI on behalf of EG&G Rocky Flats, Inc. EG&G's Project Engineer for this Study was Mr. R.A. Applehans of EG&G's Facilities Engineering, Plant Civil-Structural Engineering (FE/PCSE).

FIGURES

FIGURES



Historical Raw Water Purchases



EXISTING PLANT RAW WATER SYSTEM

TREATED SEWAGE/PROCESS WASTEWATER RECYCLE STUDY

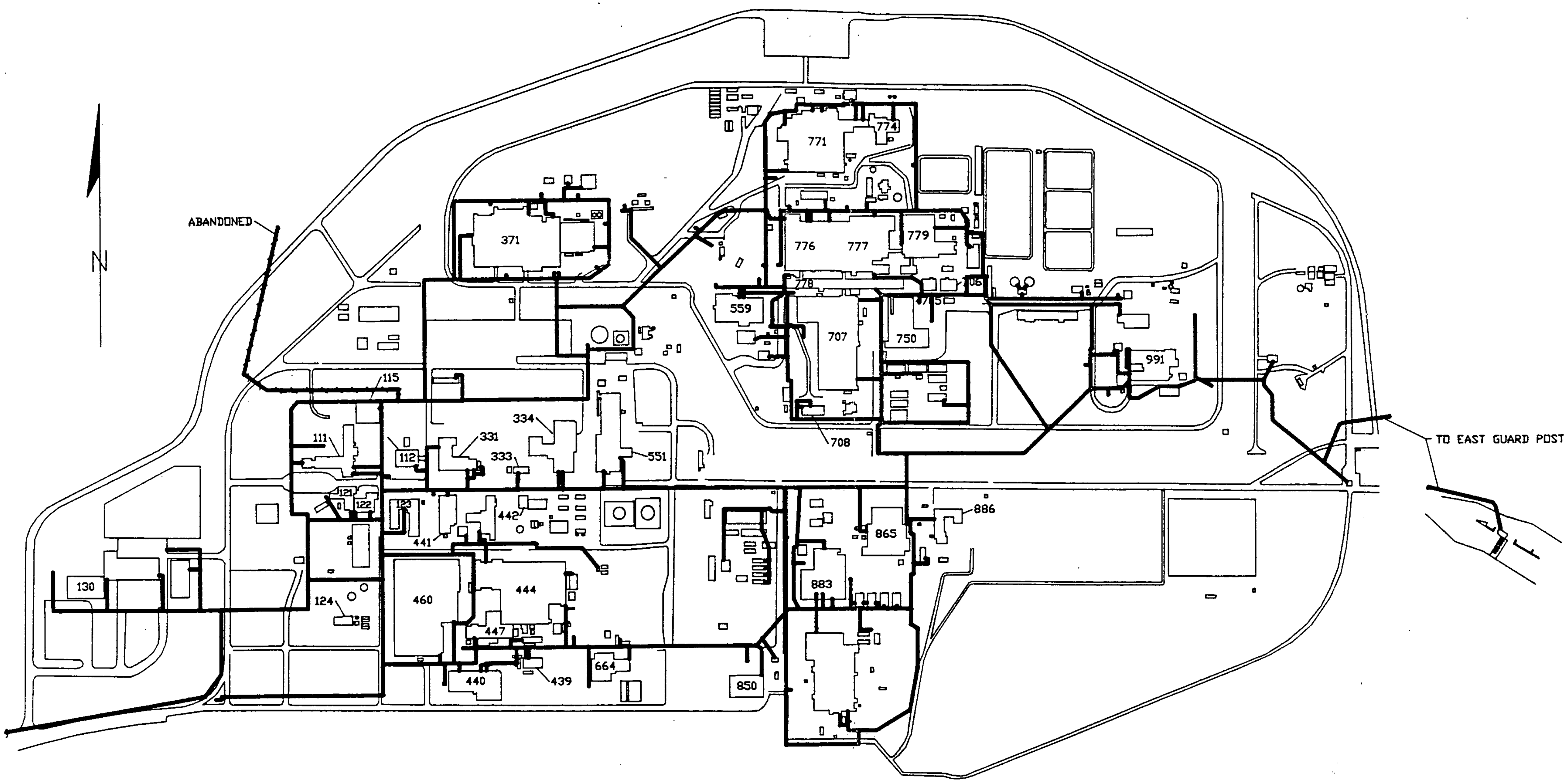
ZERO OFFSITE WATER DISCHARGE STUDY

PROJECT: 208.01.11.40

DATE: DECEMBER 1990

FIGURE 2

RWSFIG2



EXISTING PLANT DOMESTIC
COLD WATER SYSTEM

TREATED SEWAGE/PROCESS WASTEWATER
RECYCLE STUDY

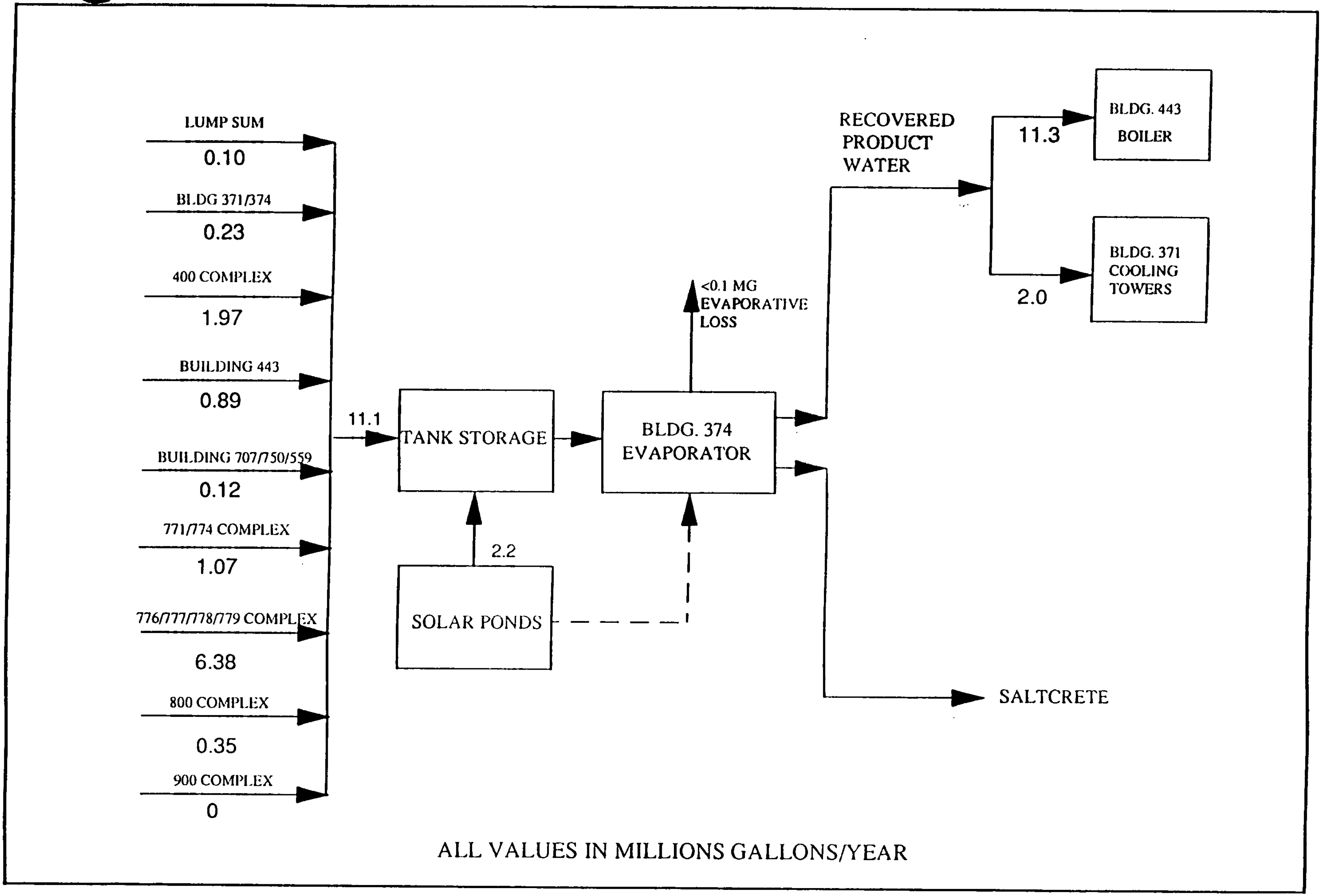
ZERO OFFSITE WATER DISCHARGE STUDY

PROJECT: 208.01.11.40

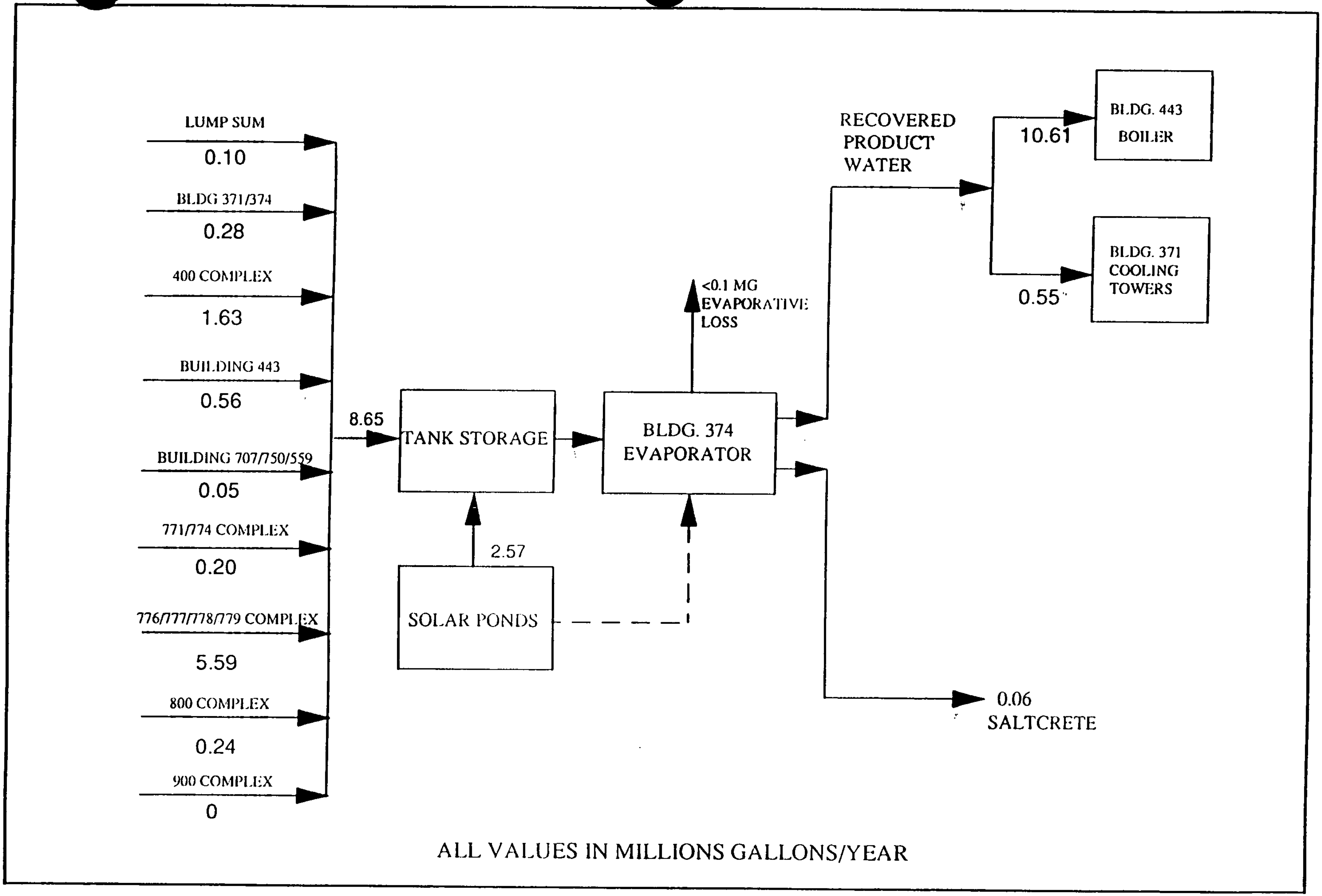
DATE: DECEMBER 1990

FIGURE 3

RFPDCV



CY 1989 Process Waste Balance



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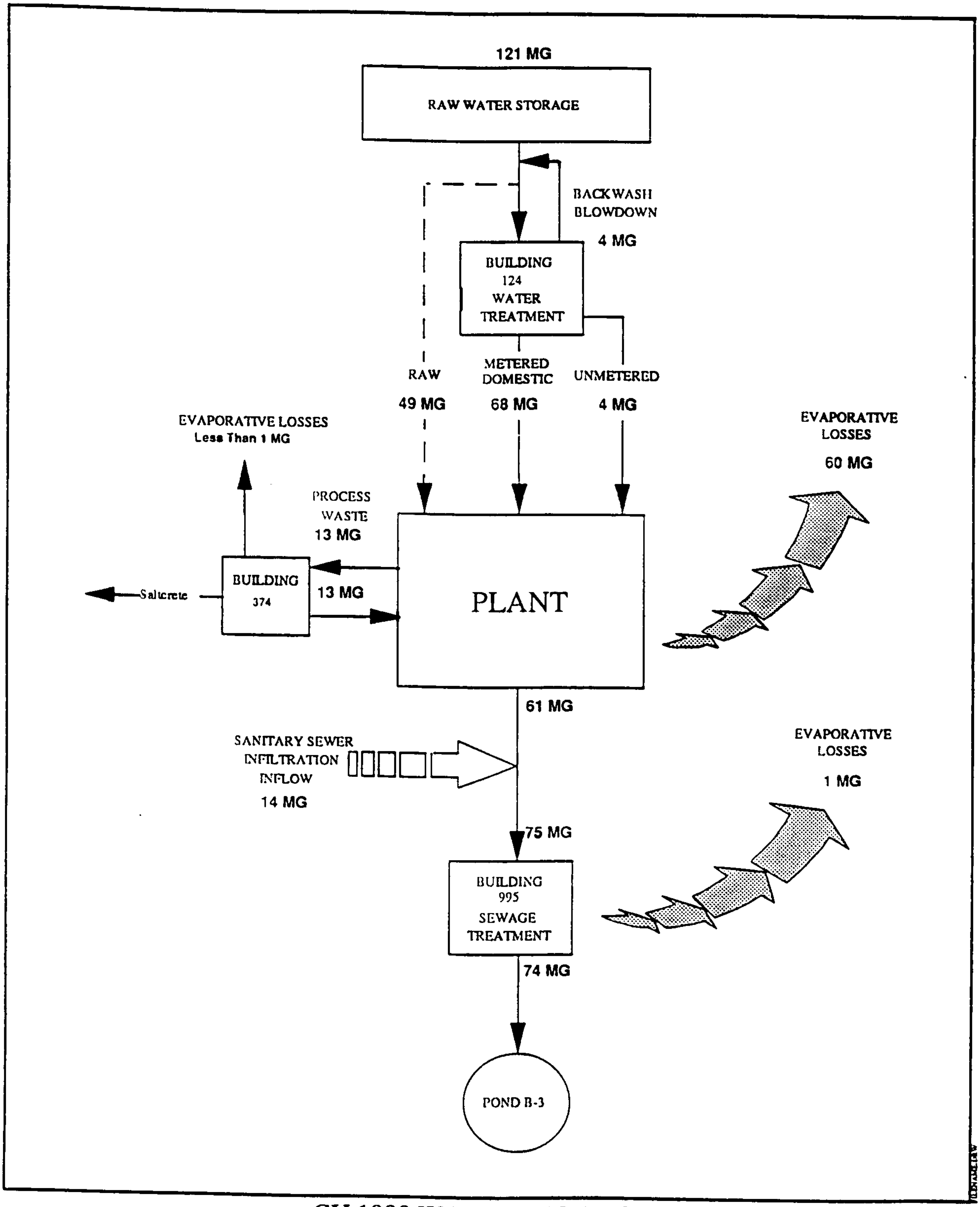
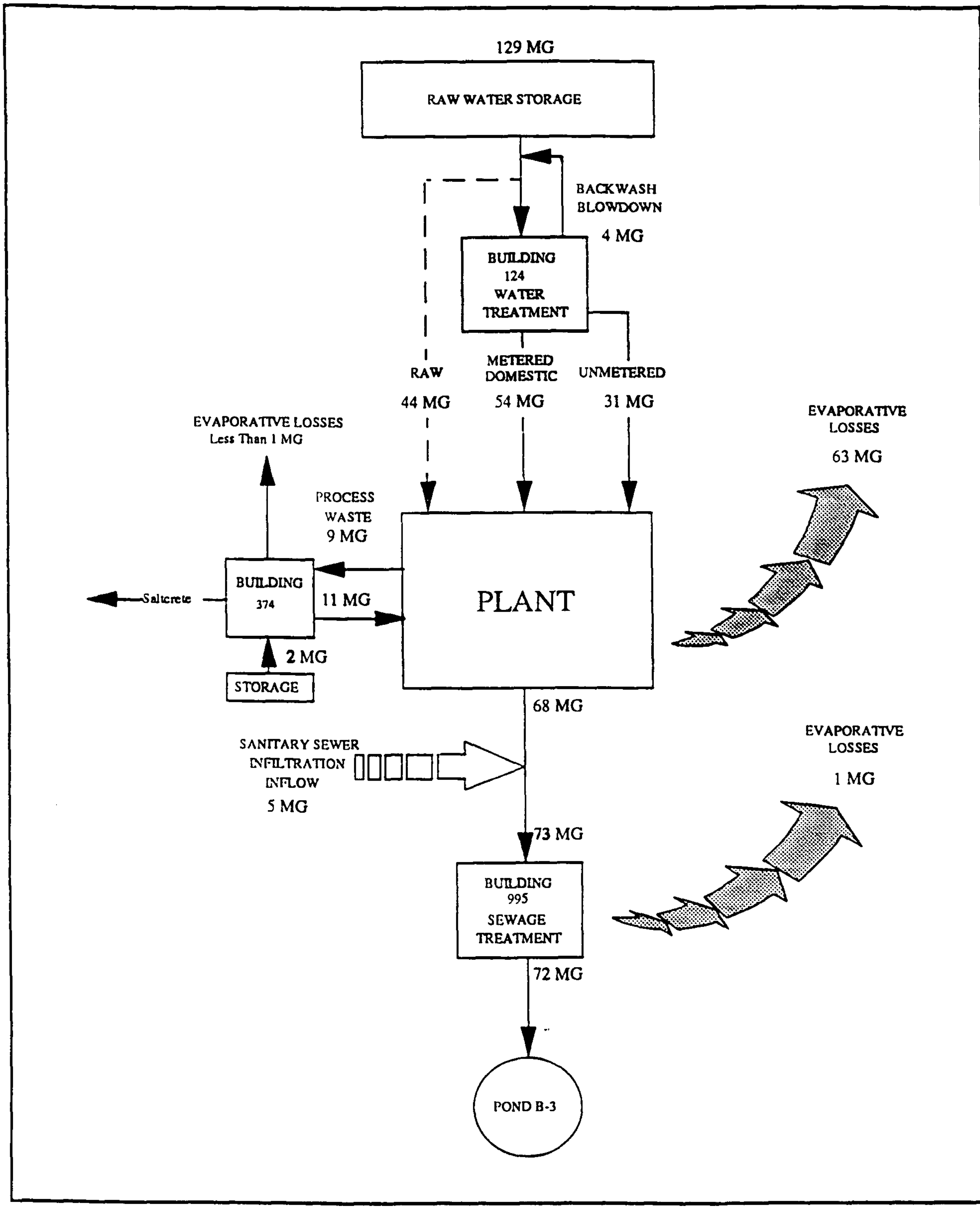


CY 1989 WATER BALANCE
ROCKY FLATS PLANT

Treated Sewage/Process Wastewater
Recycle Study
Zero-Offsite Water Discharge

PROJECT 208.0111

FIGURE 6

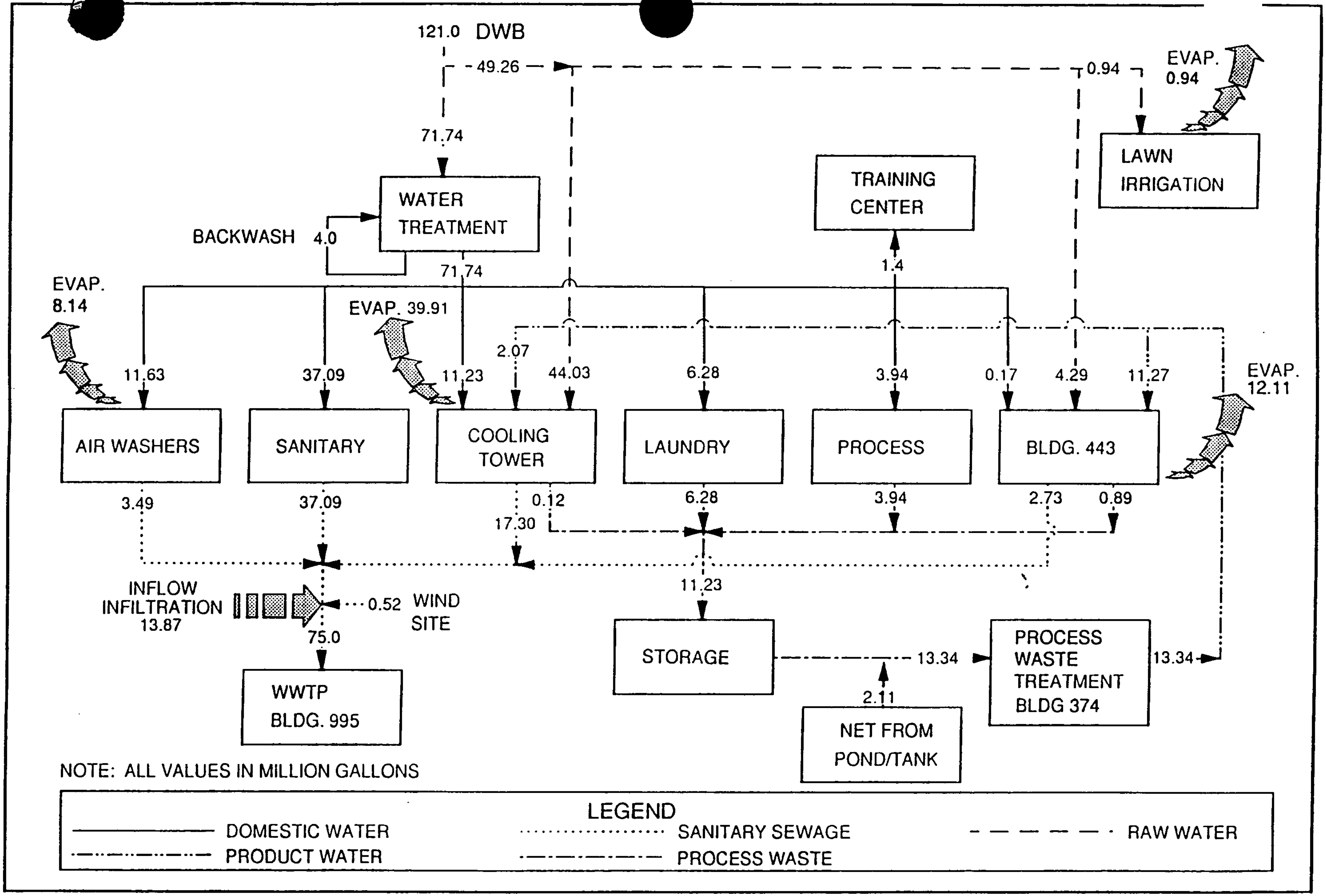


CY 90 WATER BALANCE
ROCKY FLATS PLANT

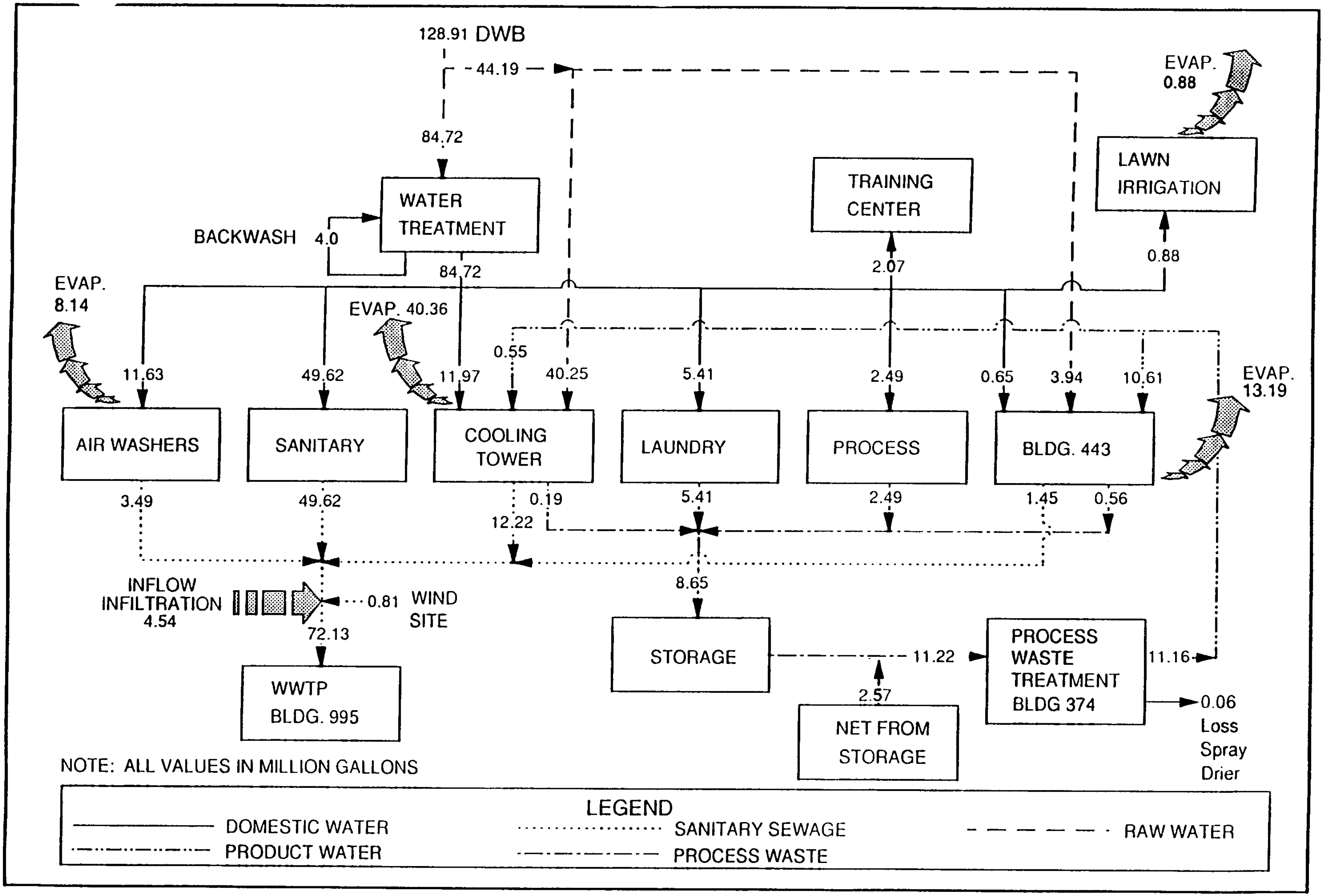
Treated Sewage/Process Wastewater
Recycle Study
Zero-Offsite Water Discharge

PROJECT 208.0111

FIGURE 7



CY 89 WATER BALANCE



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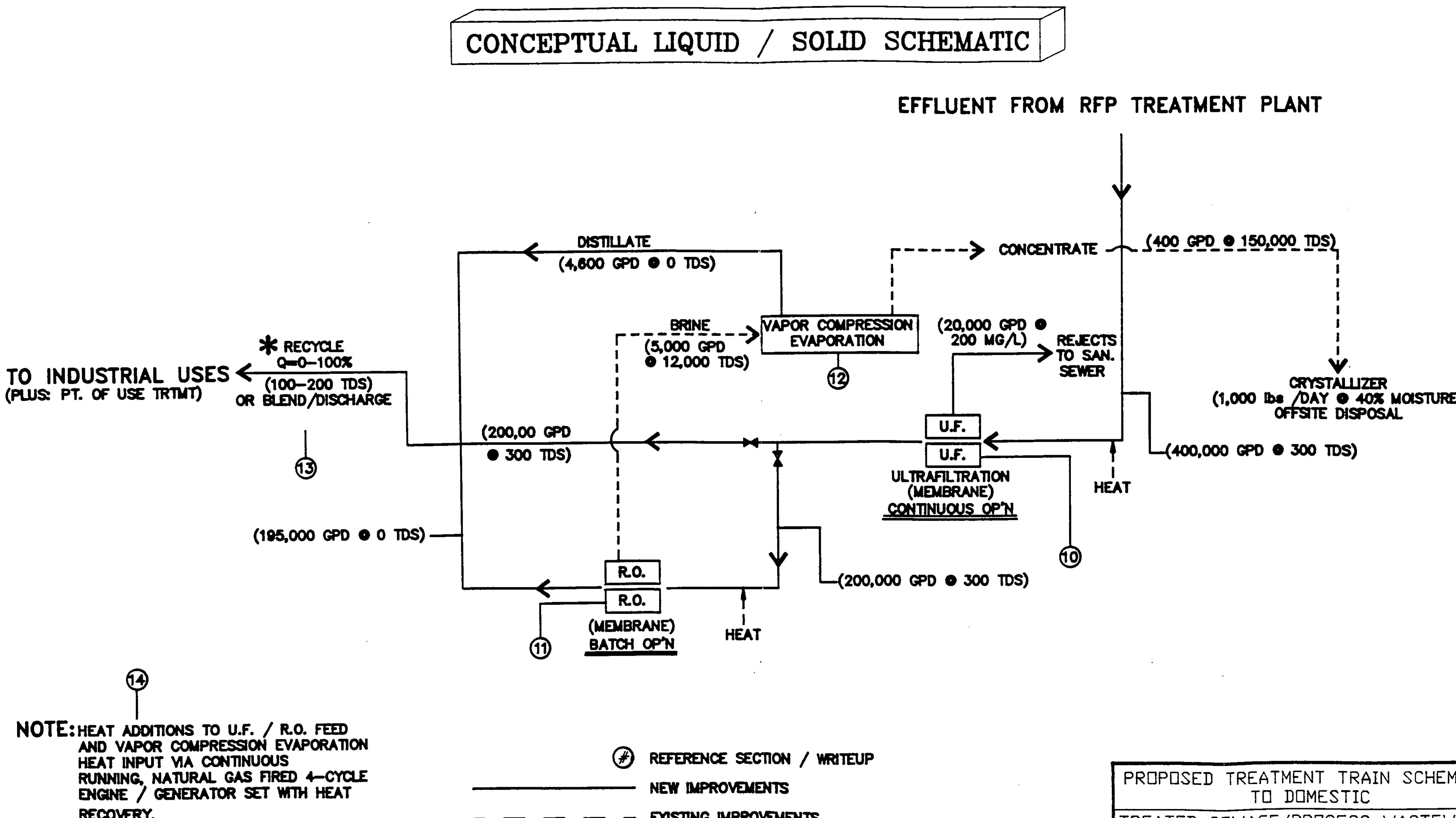
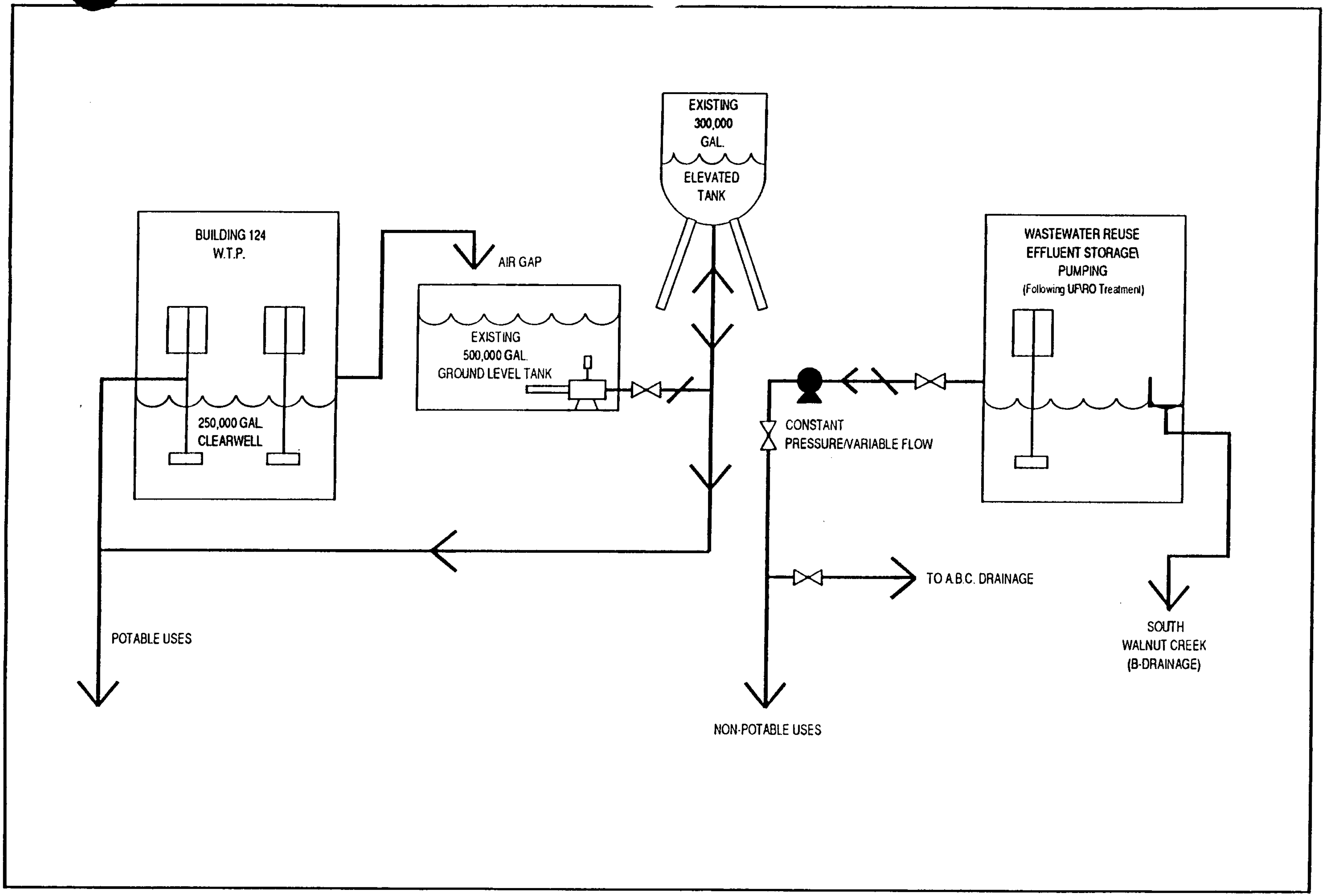


PROPOSED TREATMENT TRAIN SCHEMATIC TO DOMESTIC		
TREATED SEWAGE/PROCESS WASTEWATER RECYCLE STUDY		
ZERO OFFSITE WATER DISCHARGE STUDY		
ASI	PROJECT: 208.01.11.40	FIGURE 10
	DATE: DECEMBER 1990	

RVSALT2

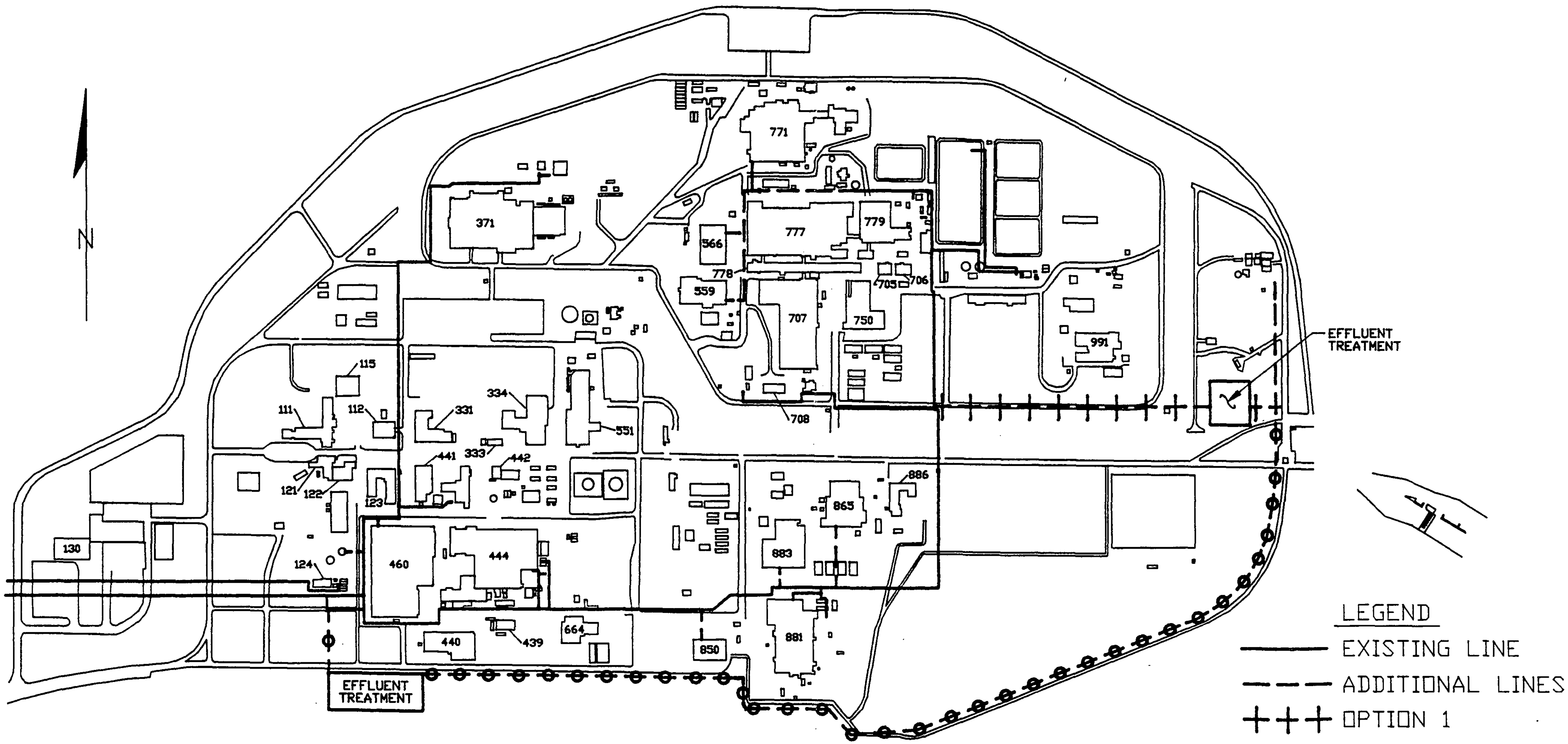


Preliminary Schematic Alternative 1

Treated Sewage/Process Wastewater Recycle Study
Zero-Offsite Water Discharge

PROJECT 20801.11

FIGURE 11



DISTRIBUTION SYSTEM
ALTERNATIVE 1

TREATED SEWAGE/PROCESS WASTEWATER
RECYCLE STUDY

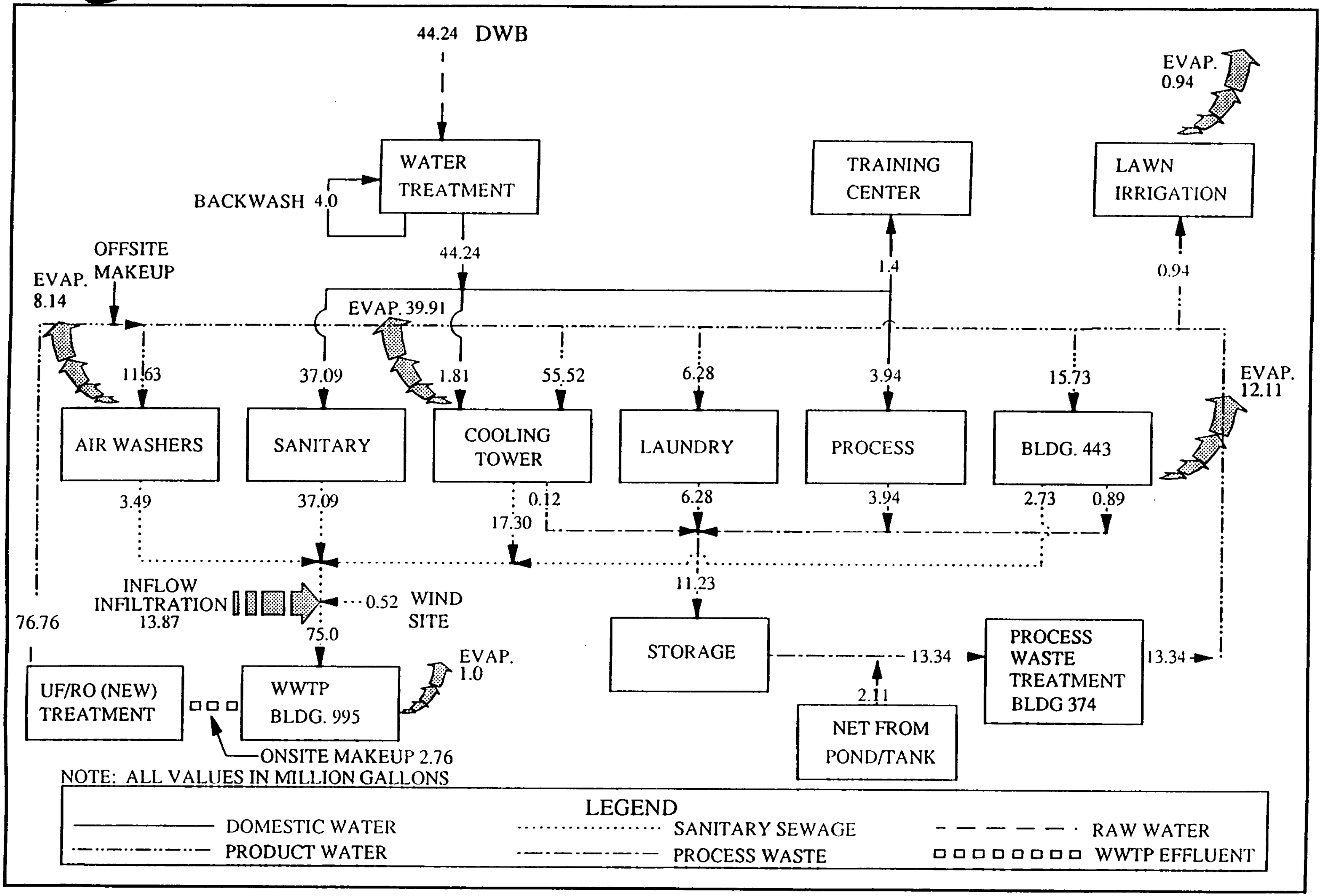
ZERO OFFSITE WATER DISCHARGE STUDY

PROJECT: 208.01.11.40

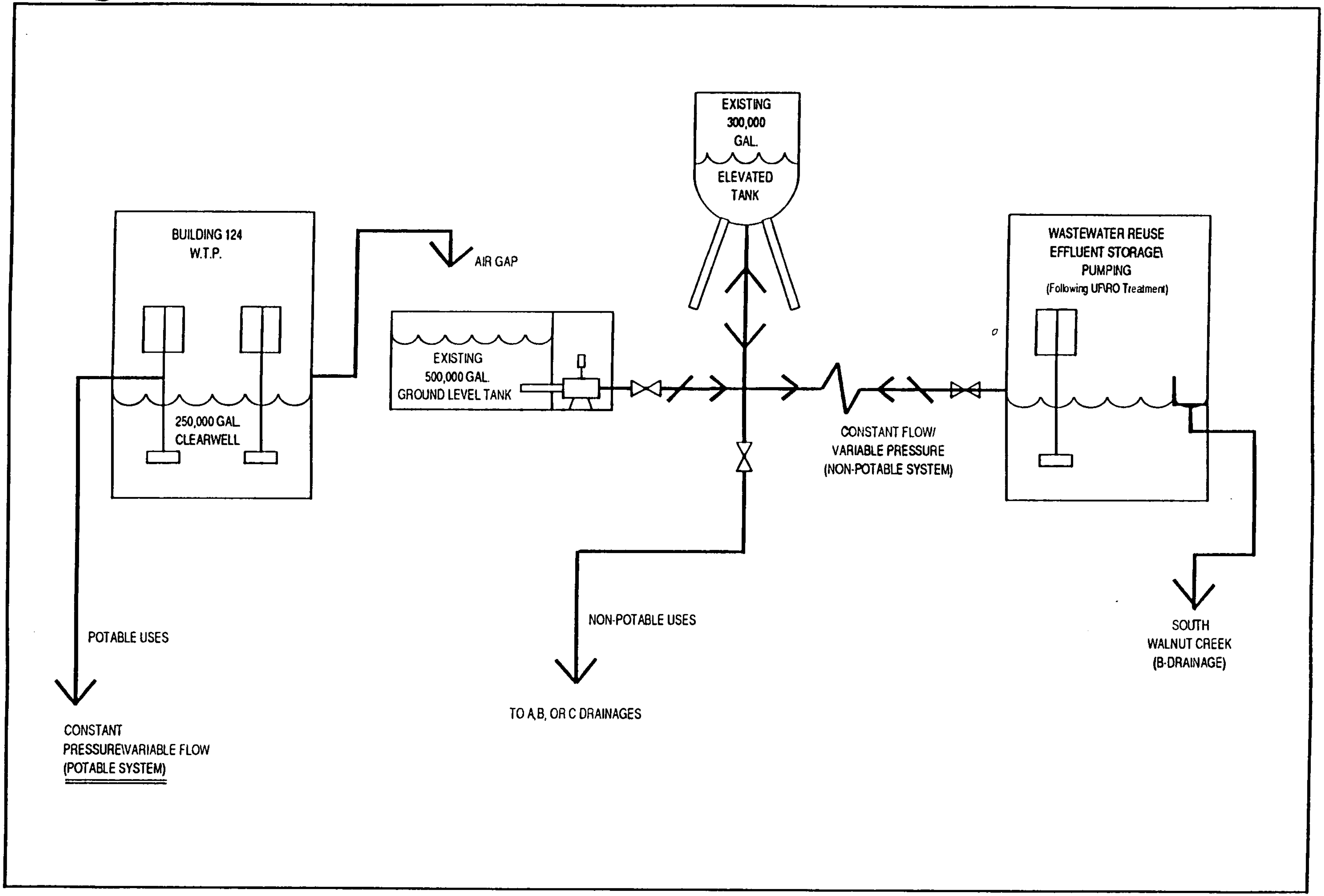
DATE: DECEMBER 1990

FIGURE 12

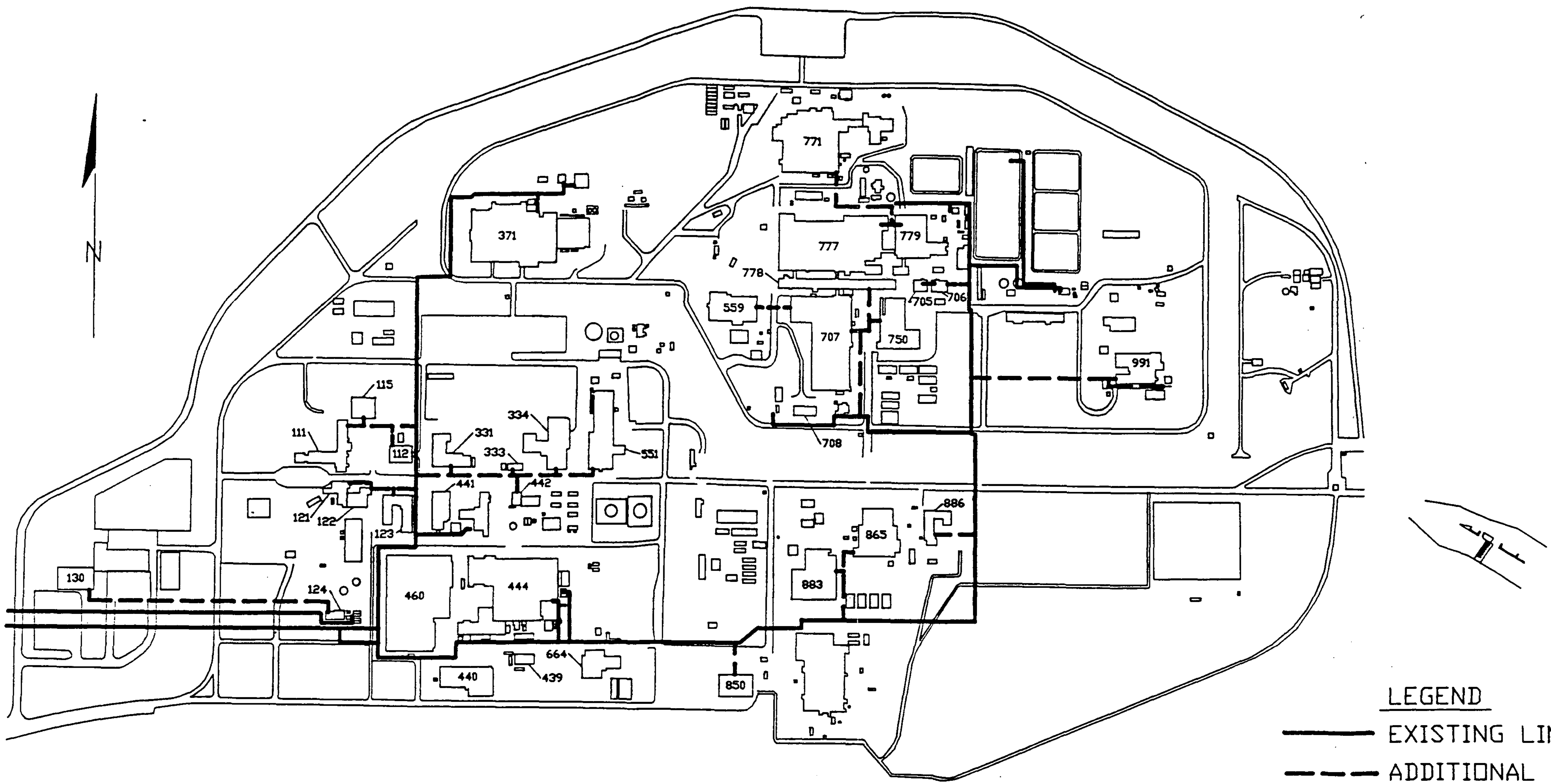
RFPRWS



CY 89 WATER BALANCE ALTERNATIVE 1



Preliminary Schematic Alternative 2



LEGEND

EXISTING LINE

ADDITIONAL LINES

DISTRIBUTION SYSTEM ALTERNATIVE 2: CONVERSION OF RAW WATER SYSTEM TO DOMESTIC

TREATED SEWAGE/PROCESS WASTEWATER RECYCLE STUDY

ZERO OFFSITE WATER DISCHARGE STUDY

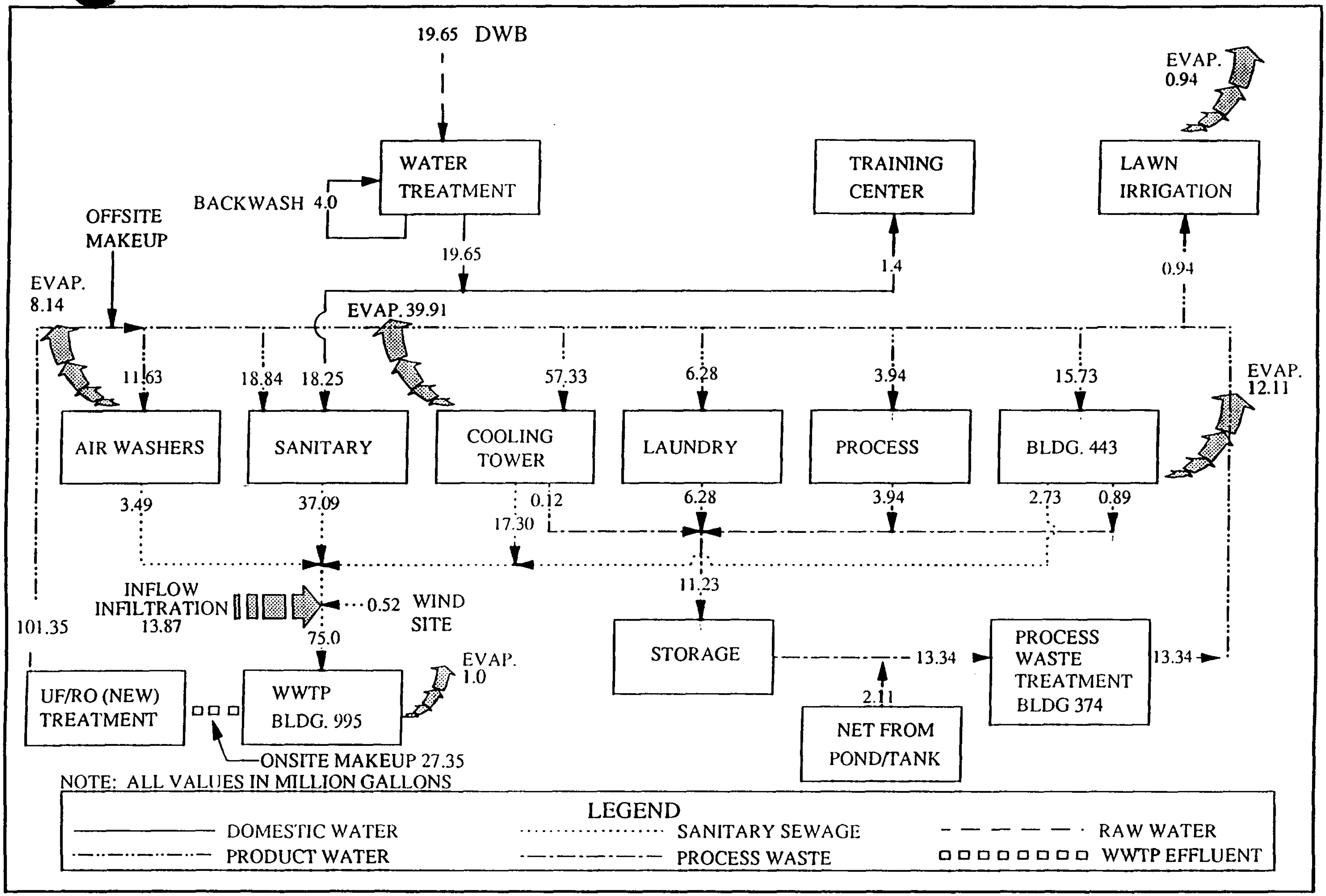
ASI

PROJECT: 208.01.11.40

DATE: DECEMBER 1990

FIGURE 15

RWSALT2

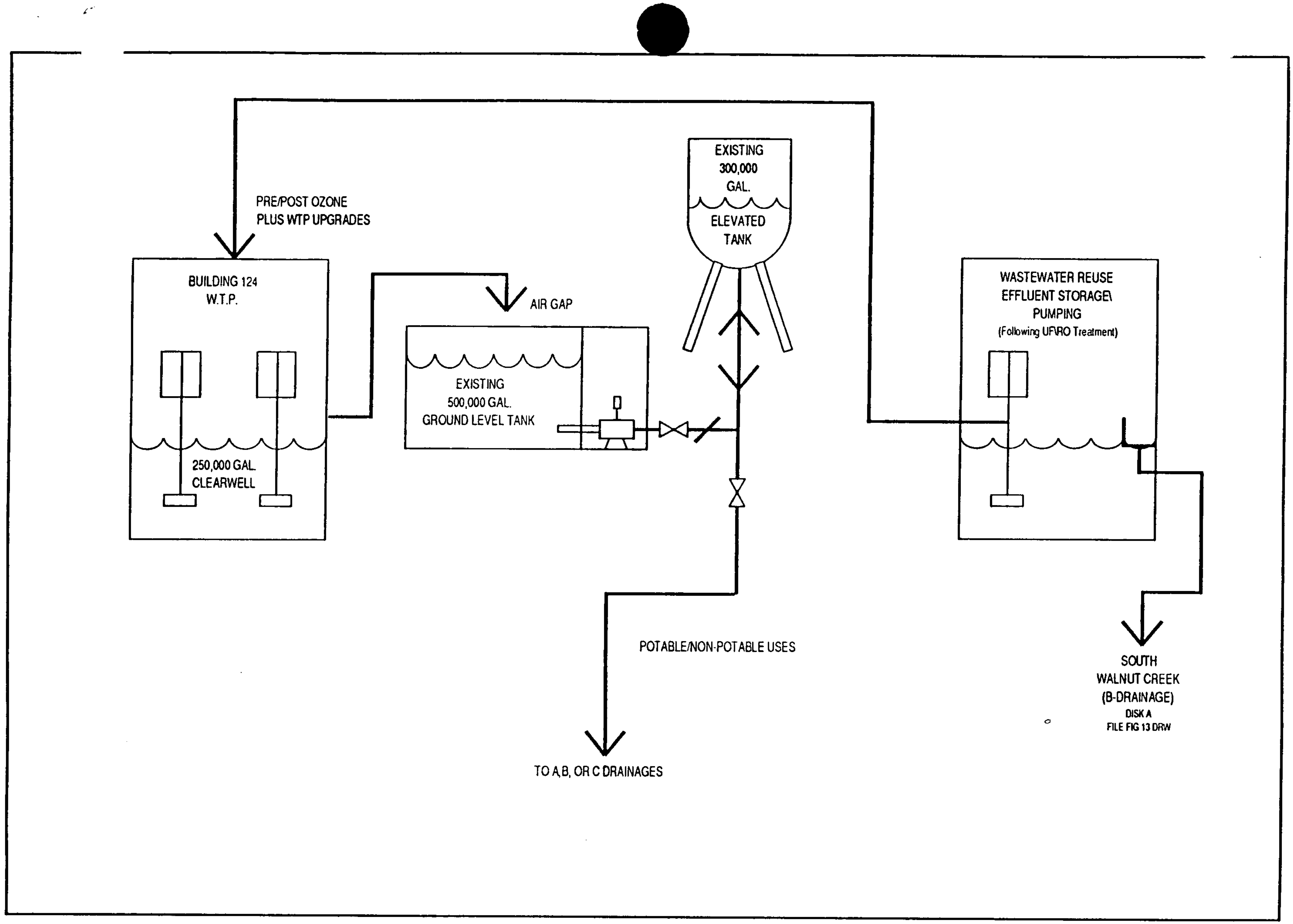


CY 89 WATER BALANCE ALTERNATIVE 2

Treated Sewage/Process Wastewater Recycle Study
Zero Offsite Water Discharge

PROJECT 208.0111

FIGURE 16



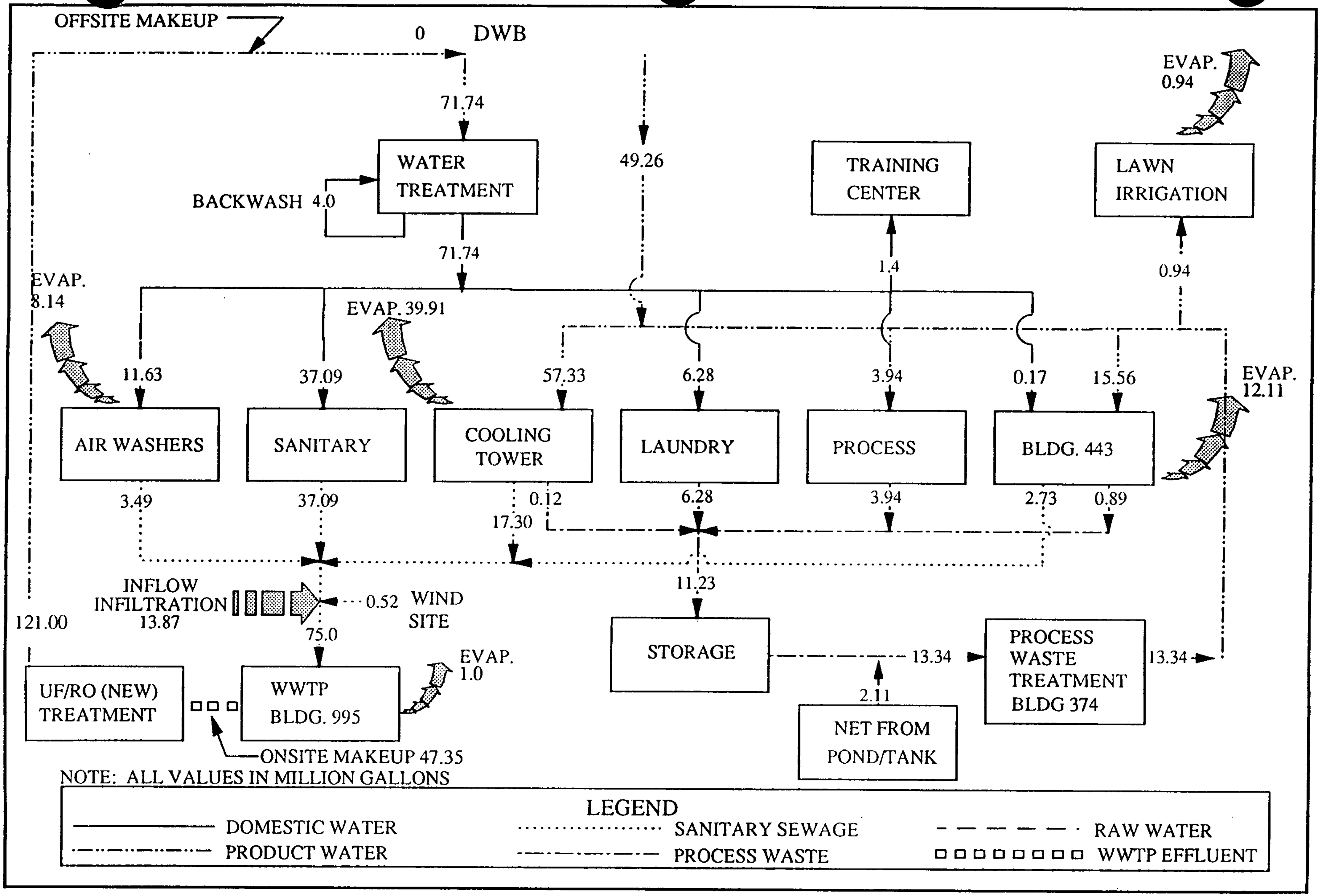
Preliminary Schematic Alternative 3

Treated Sewage/Process Wastewater Recycle Study

Zero-Offsite Water Discharge

PROJECT 20801.11

FIGURE 17



CY 89 WATER BALANCE ALTERNATIVE 3

Treated Sewage/Process Wastewater Recycle Study
Zero Offsite Water Discharge

PROJECT 208.0111

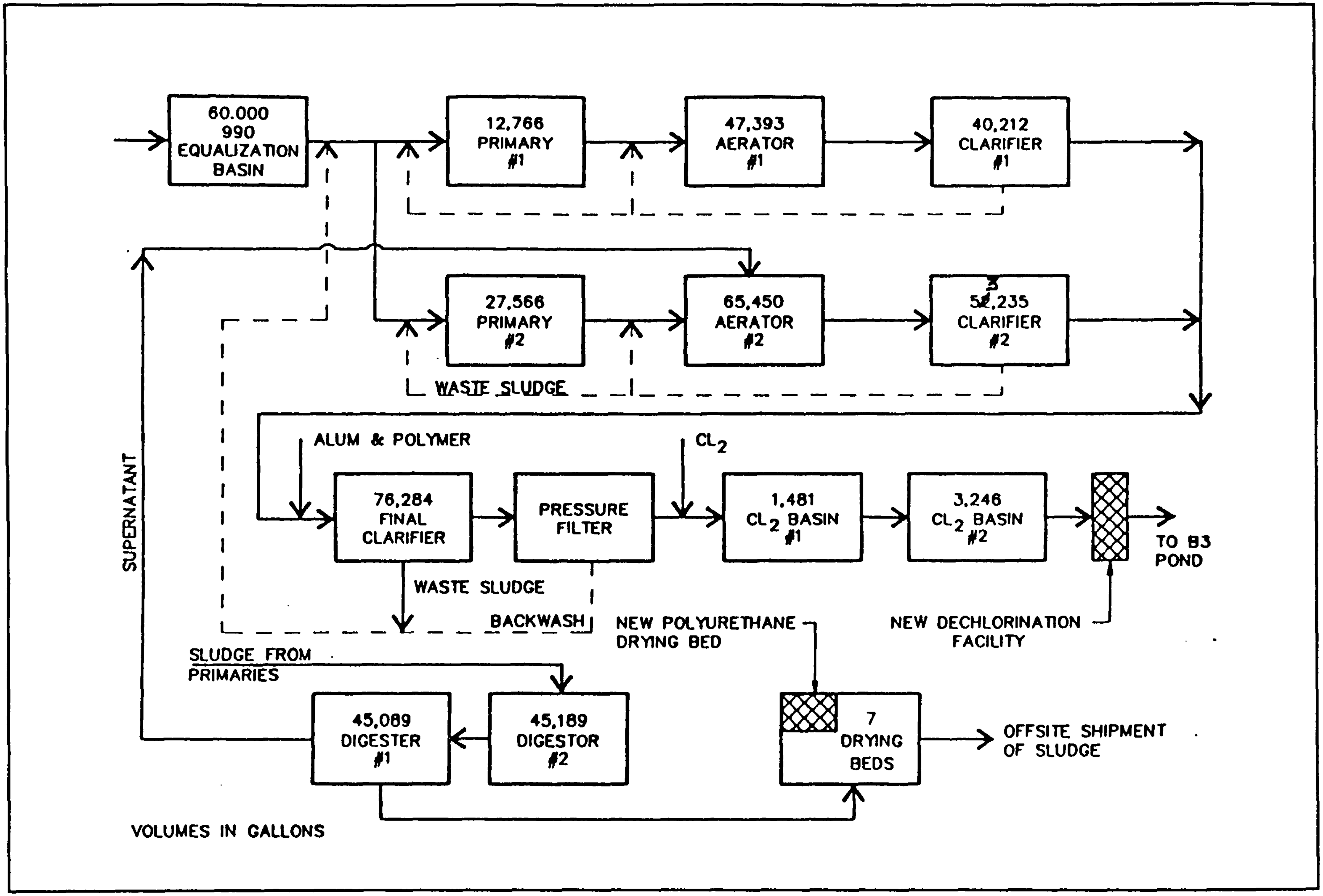
FIGURE 18

A

APPENDIX A

SEWAGE TREATMENT PLANT

SCHEMATIC (BLDG 995)

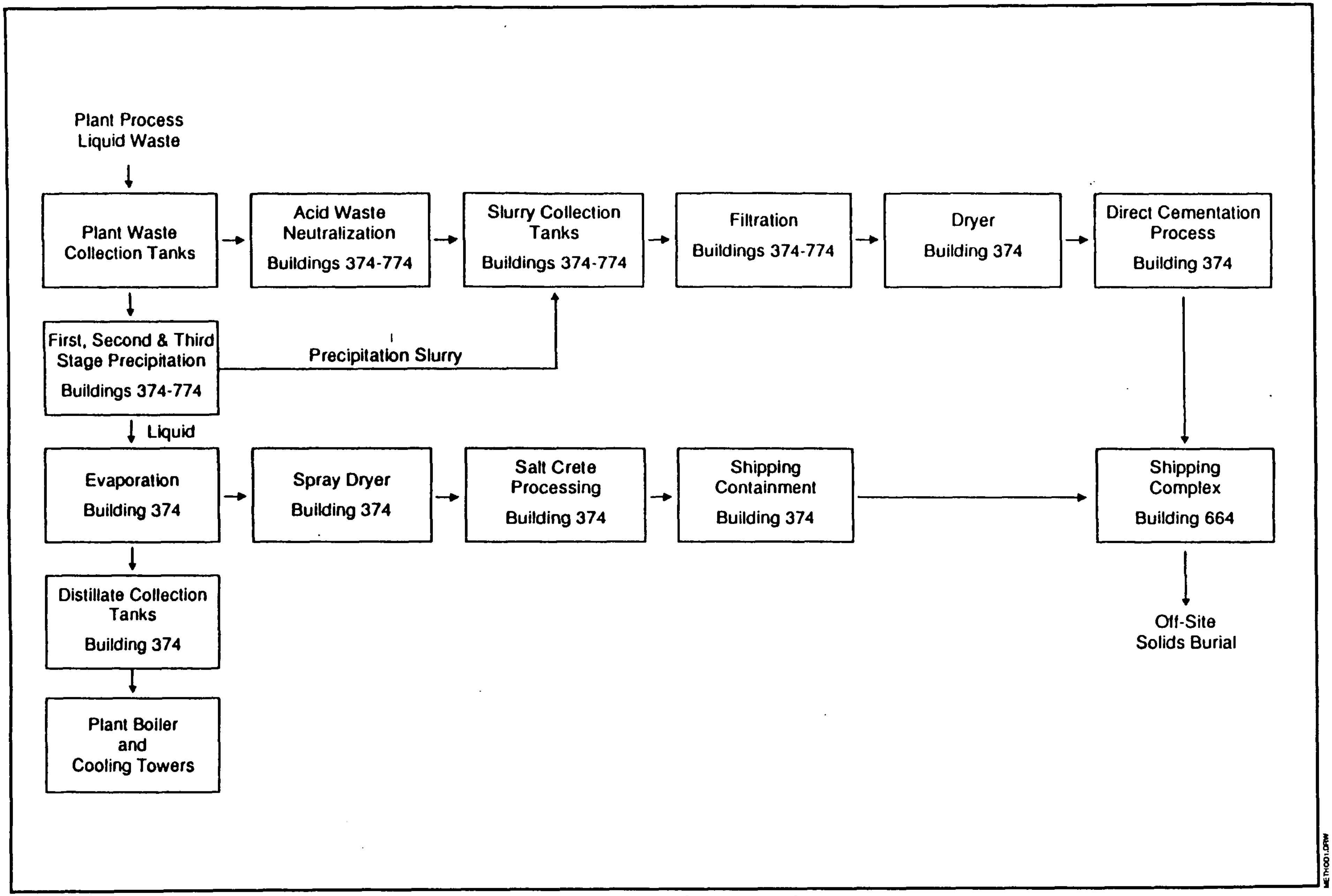


Sewage Treatment Plant Schematic

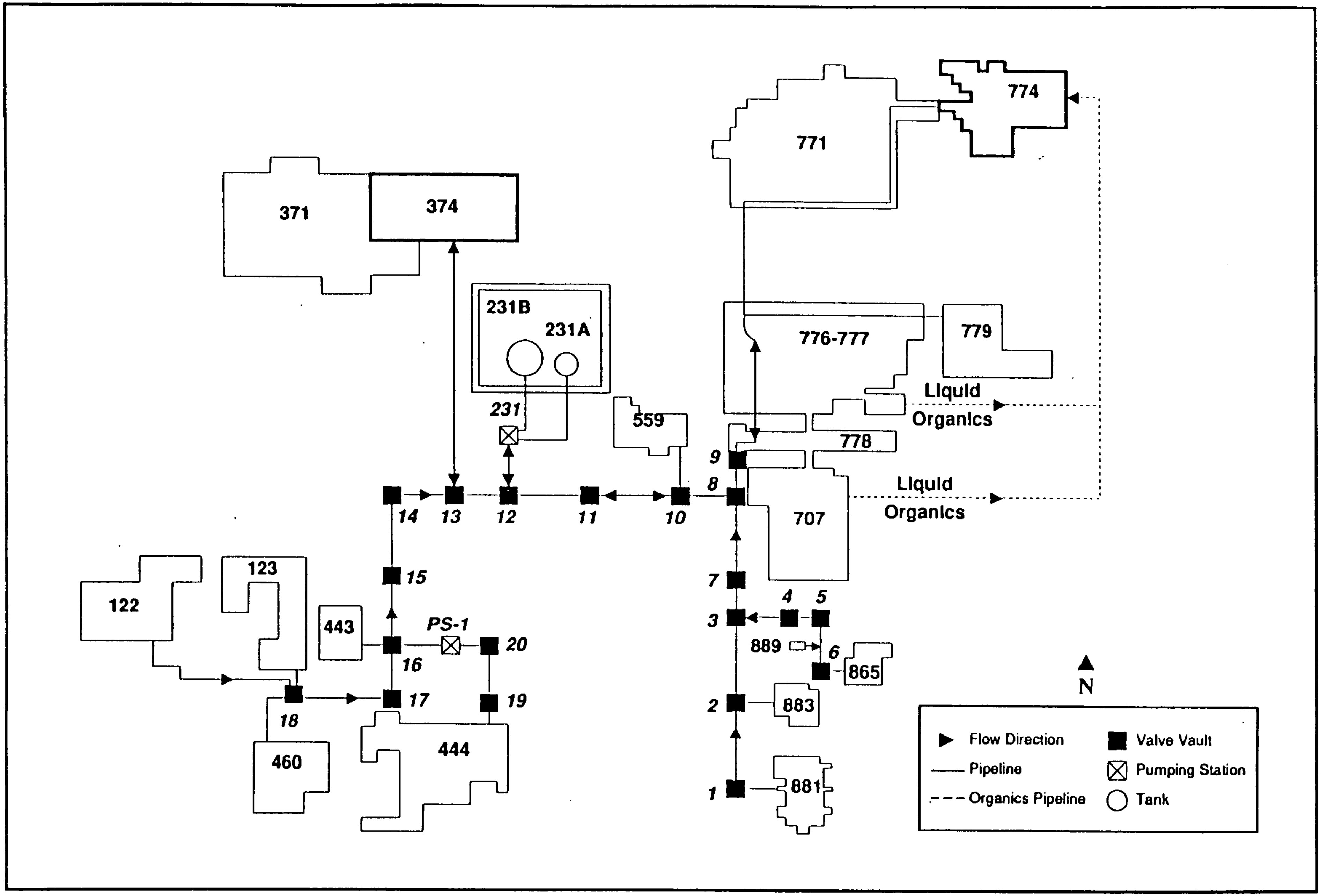
B

APPENDIX B

PROCESS WASTEWATER COLLECTION/TREATMENT SCHEMATIC (BLDG 374)



Building 374 Schematic

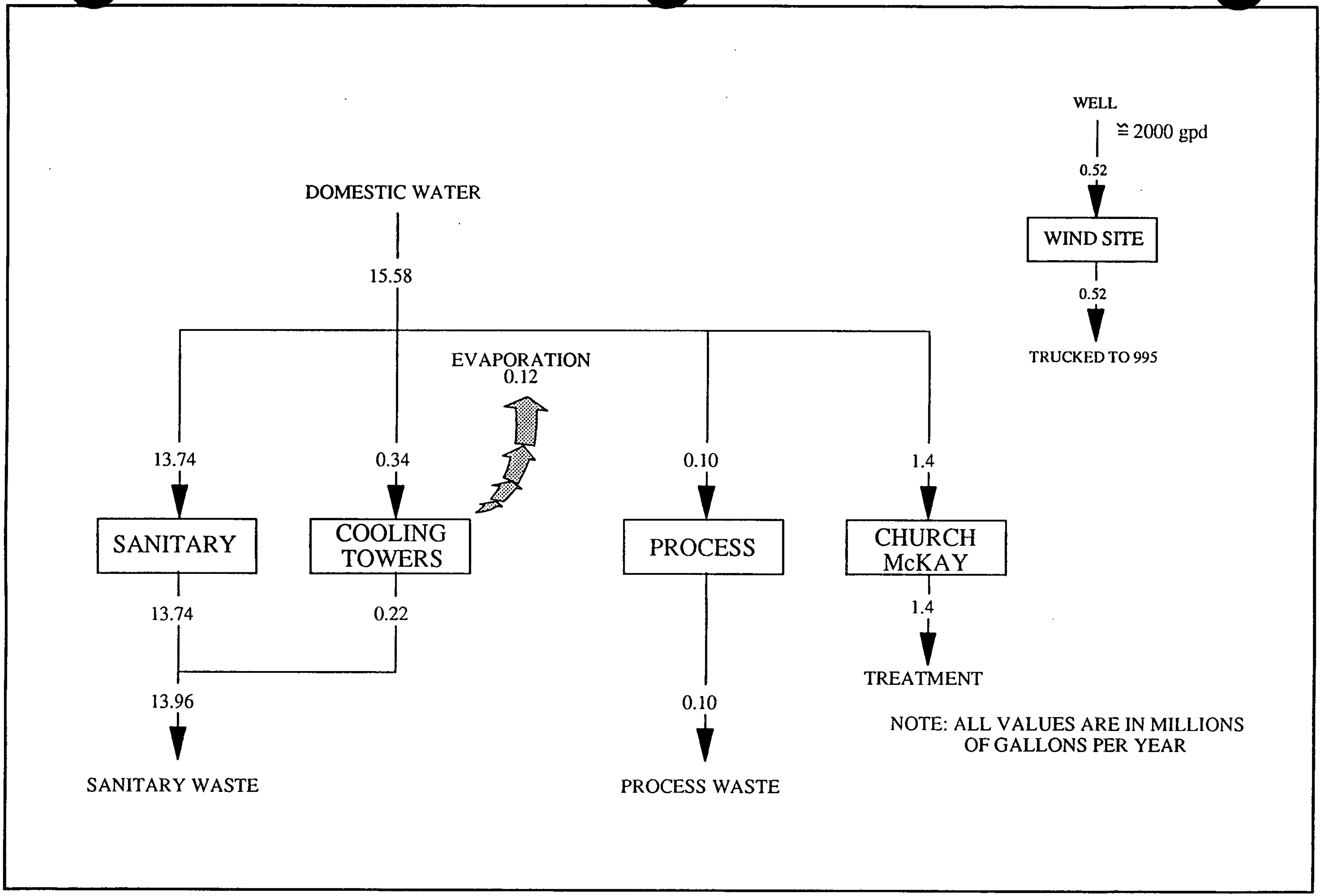


Process Waste Collection System

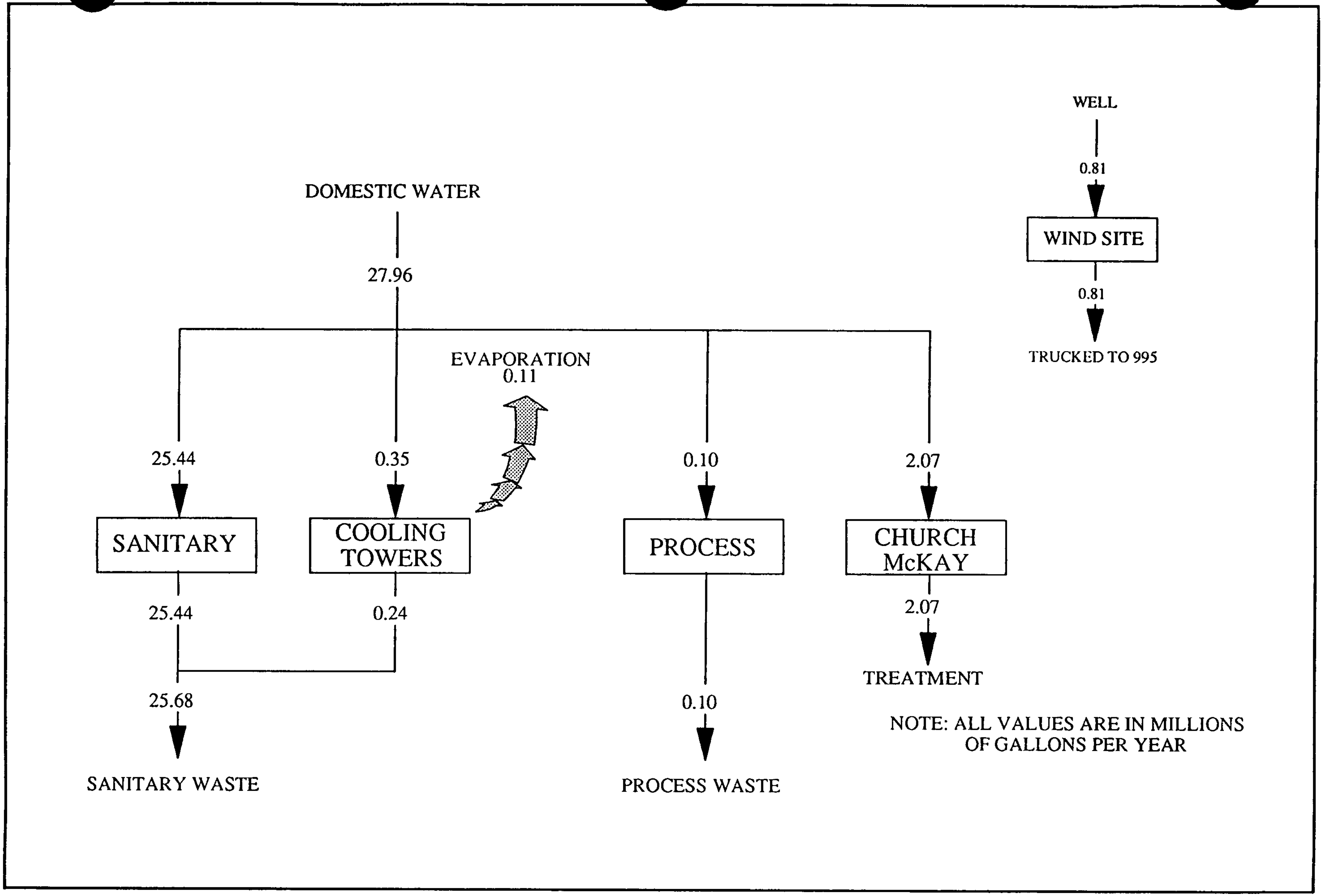
C

APPENDIX C

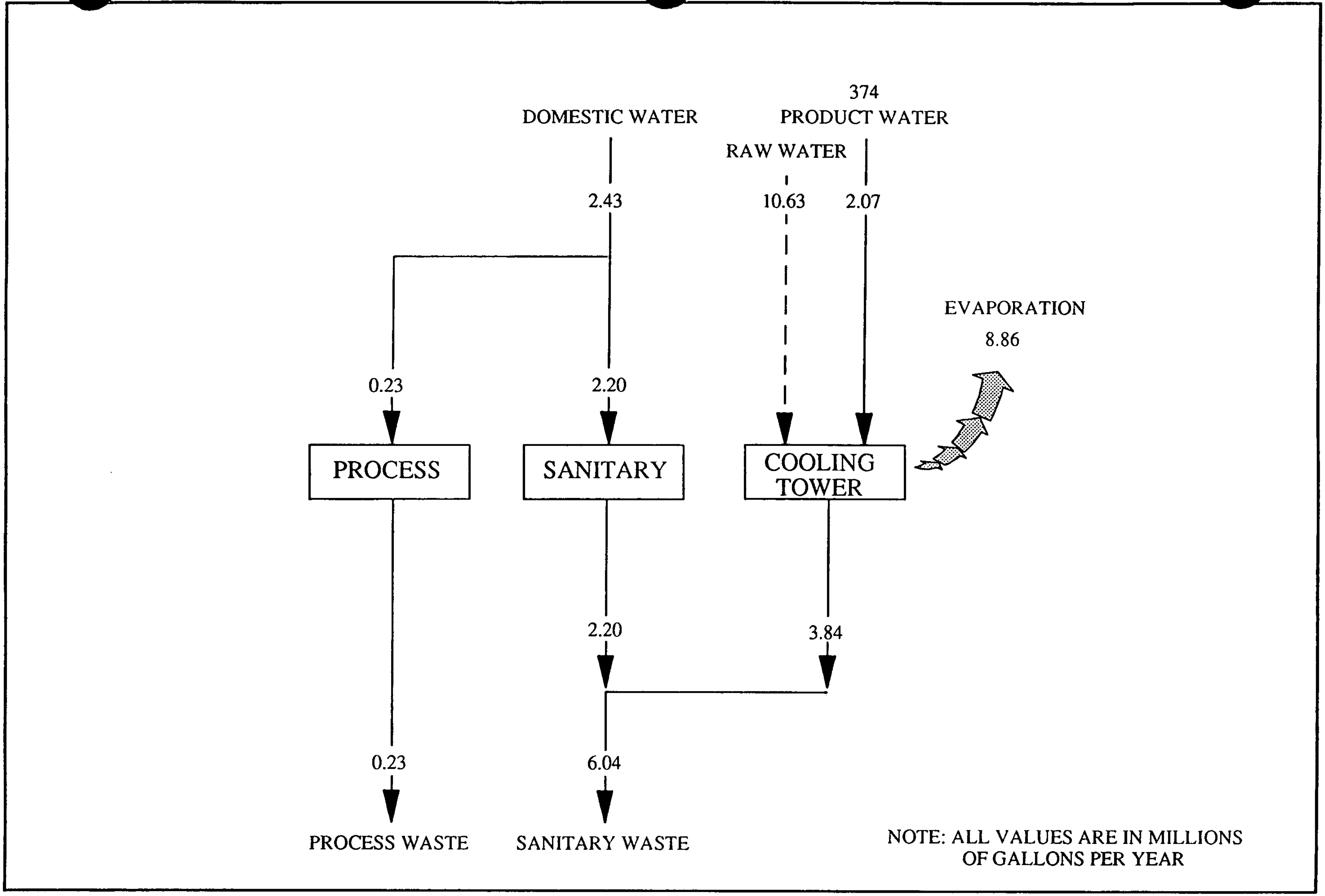
PROCESS WATER/SANITARY WATER BALANCES



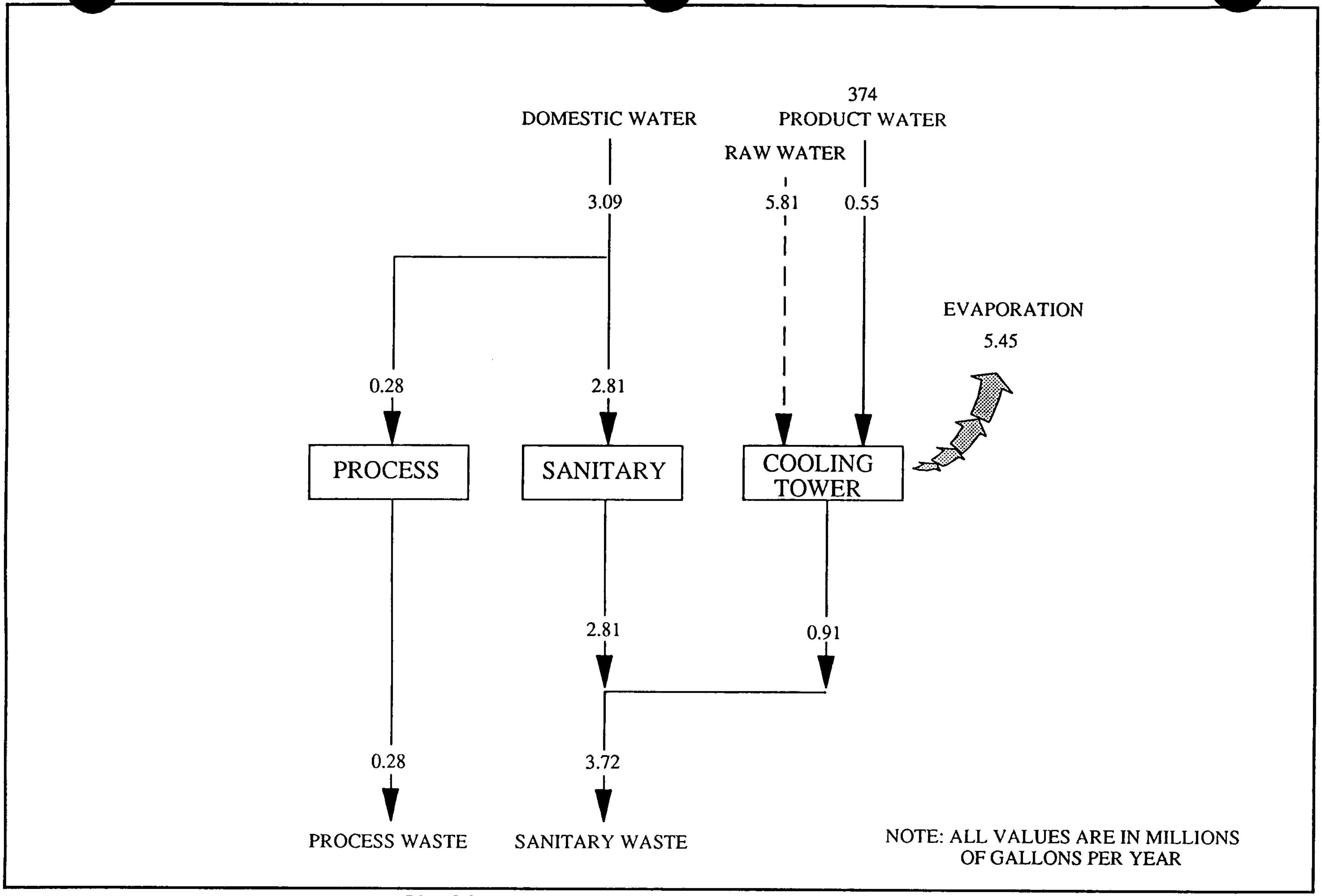
CY 89 Water Balance Lump Sum Area



CY 90 Water Balance Lump Sum Area



CY 89 Water Balance Buildings 371/374



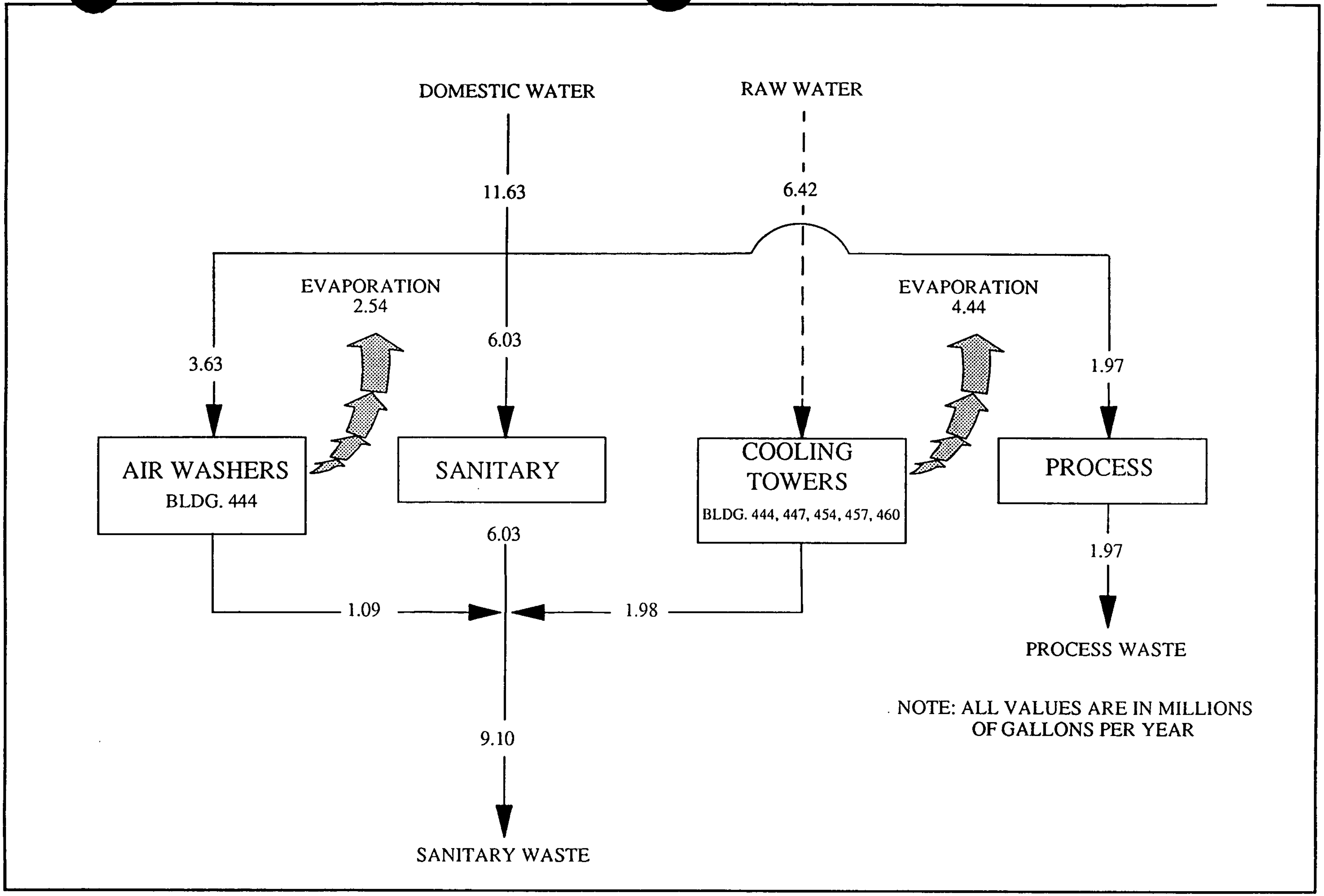
CY 90 Water Balance Buildings 371/374

Treated Sewage/Process Wastewater Recycle Study

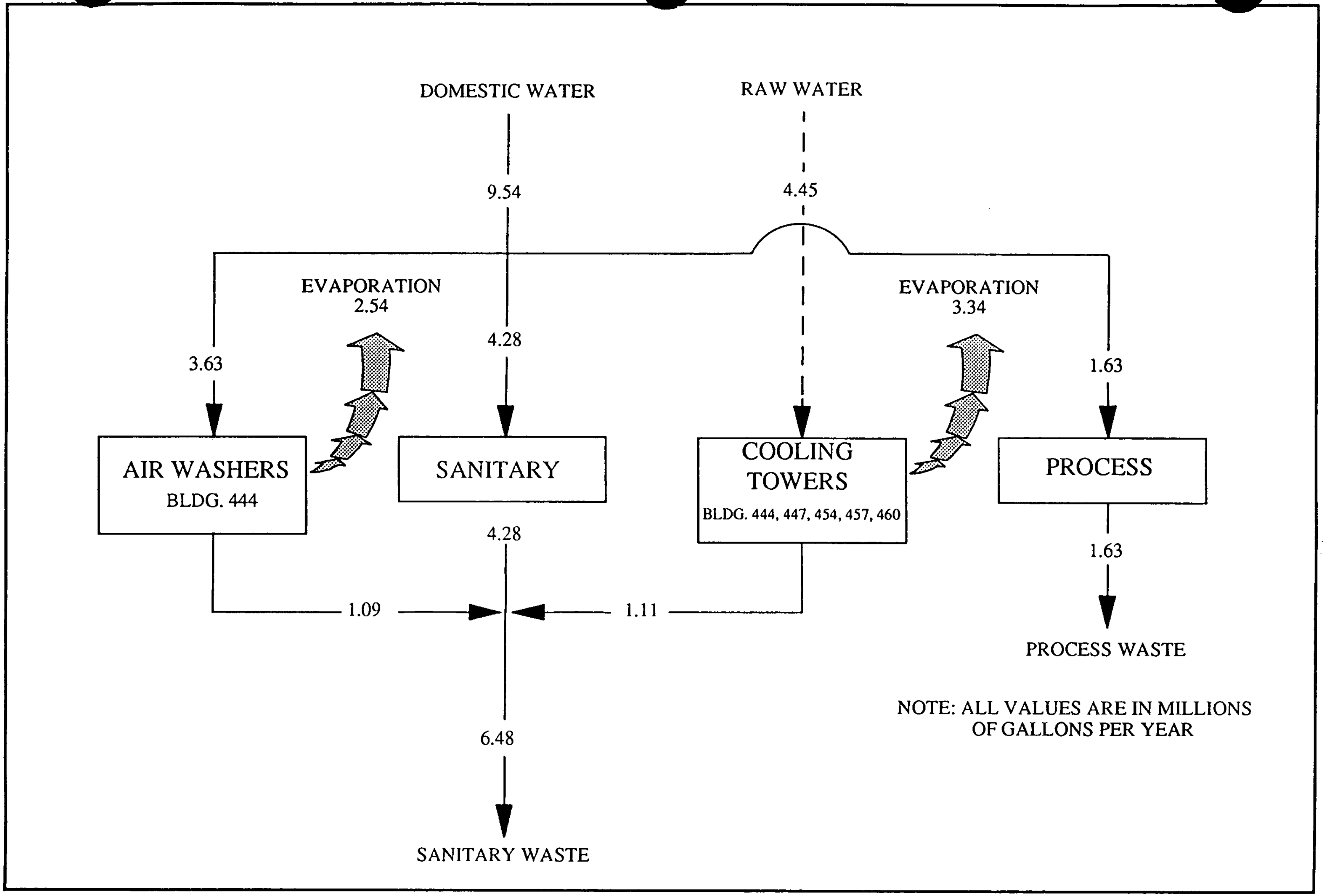
Zero-Offsite Water Discharge

PROJECT 20801.11

FIGURE C-2a



CY 89 Water Balance 400 Complex



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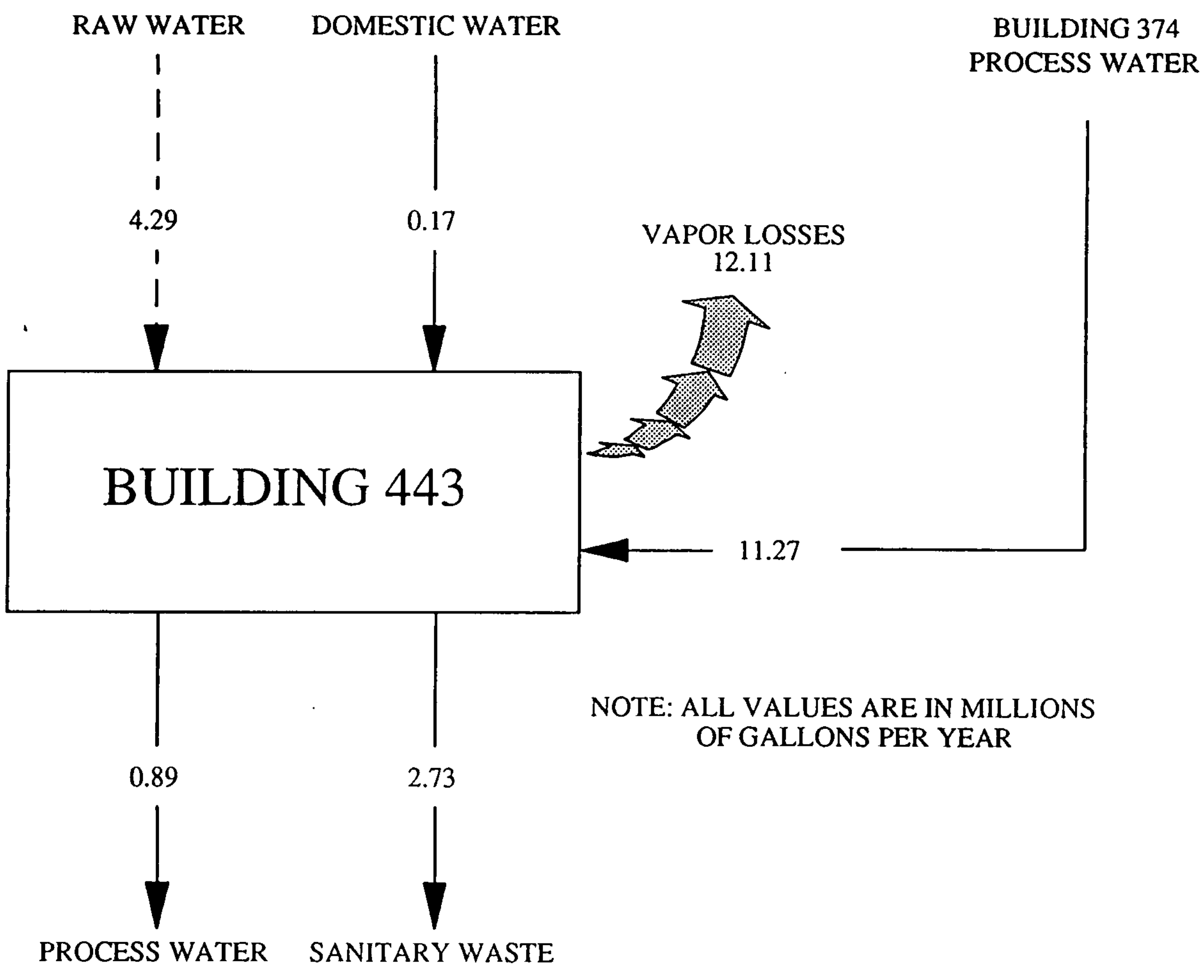
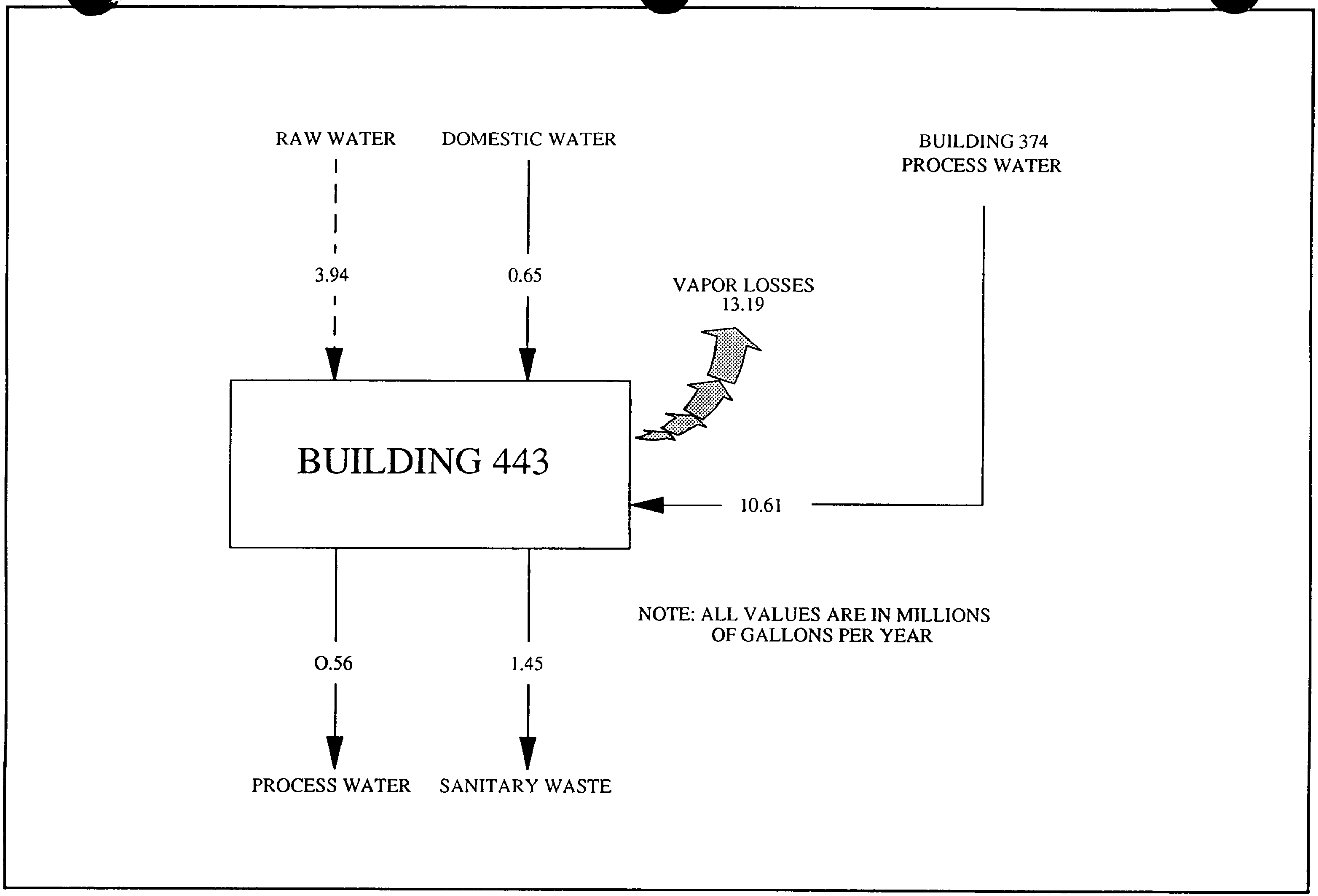


CY 89 Water Balance Building 443



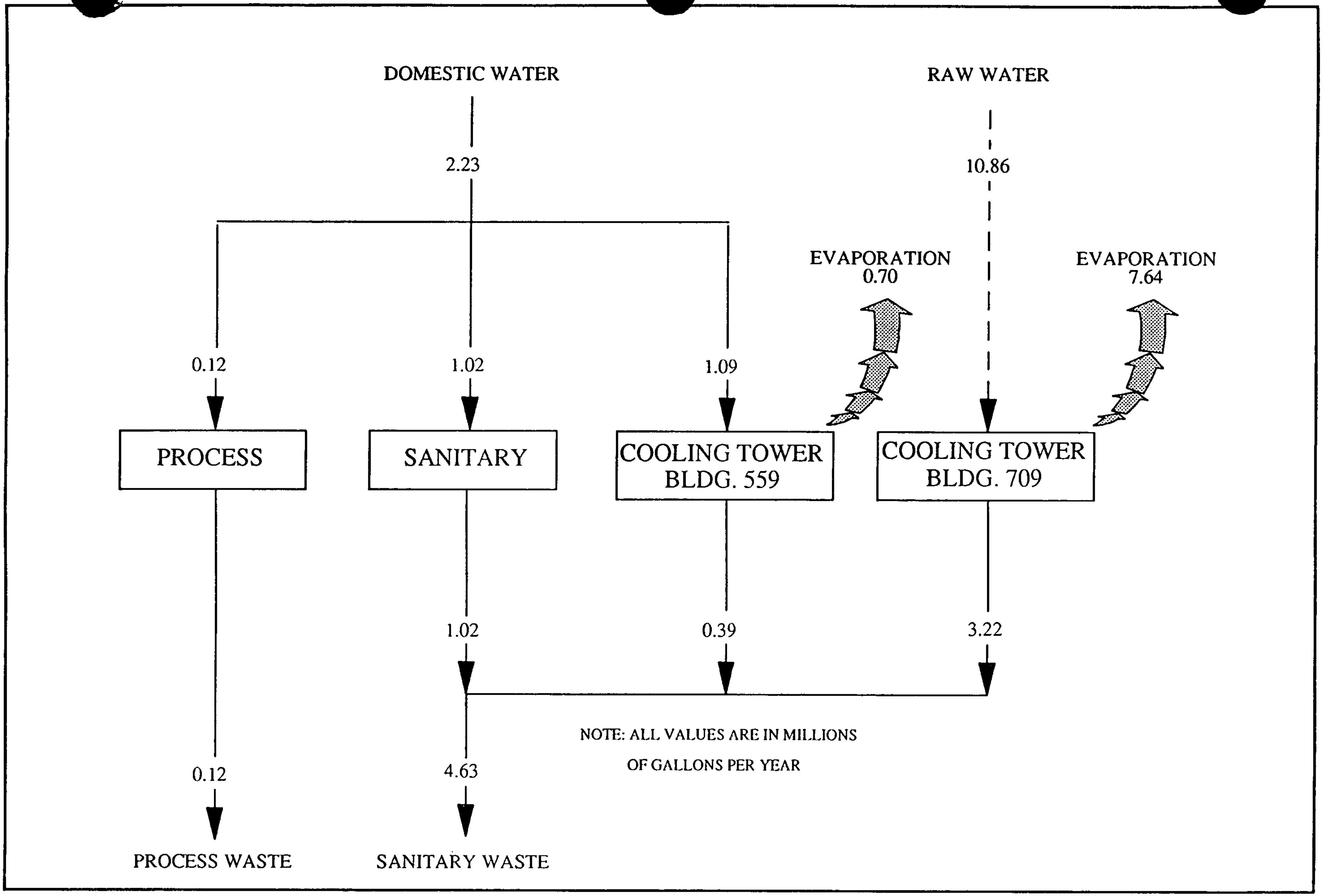
CY 90 Water Balance Building 443

Treated Sewage/Process Wastewater Recycle Study

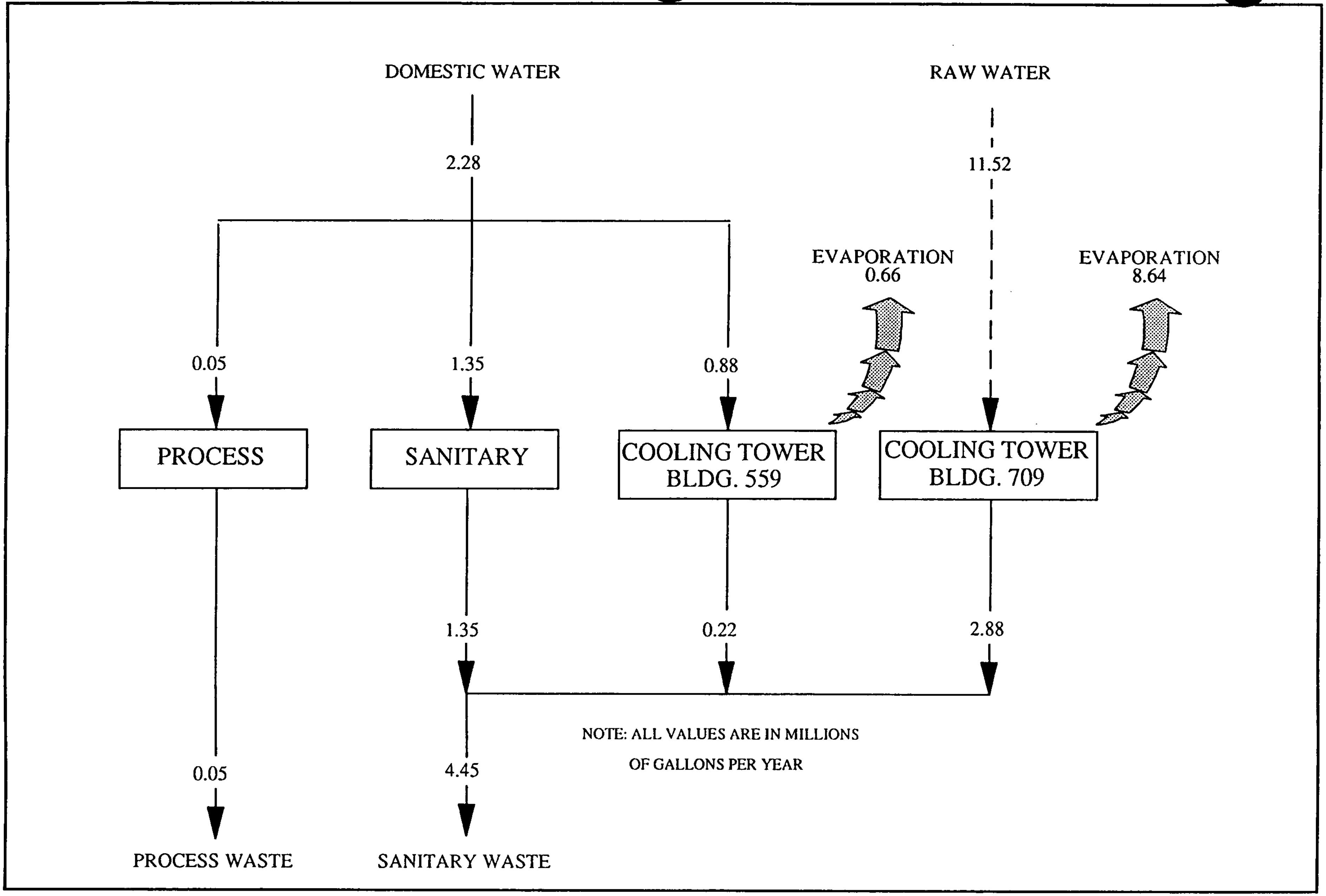
Zero-Offsite Water Discharge

PROJECT 20801.11

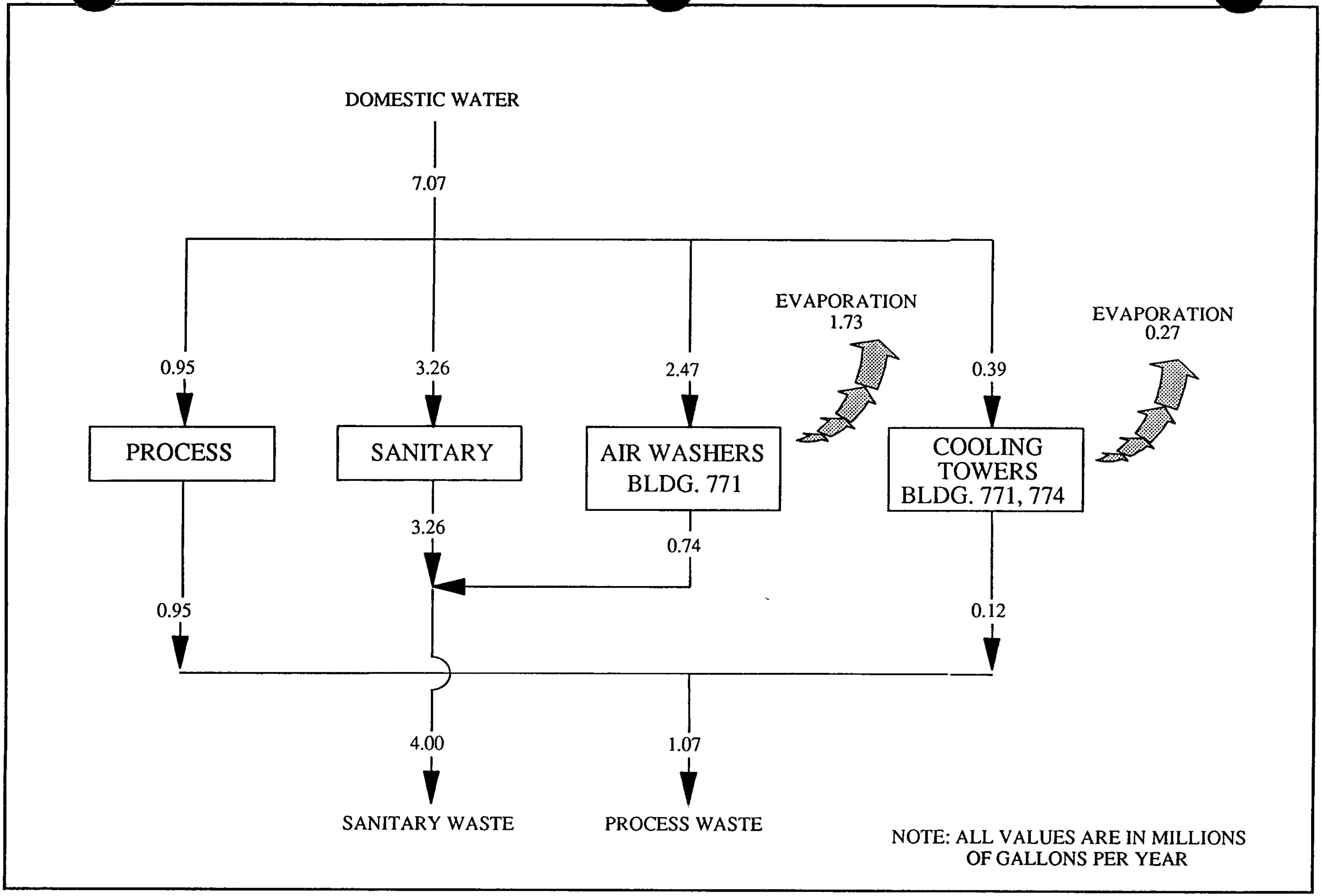
FIGURE C-4a



CY 89 Water Balance Buildings 707, 750, 559



CY 90 Water Balance Buildings 707, 750, 559



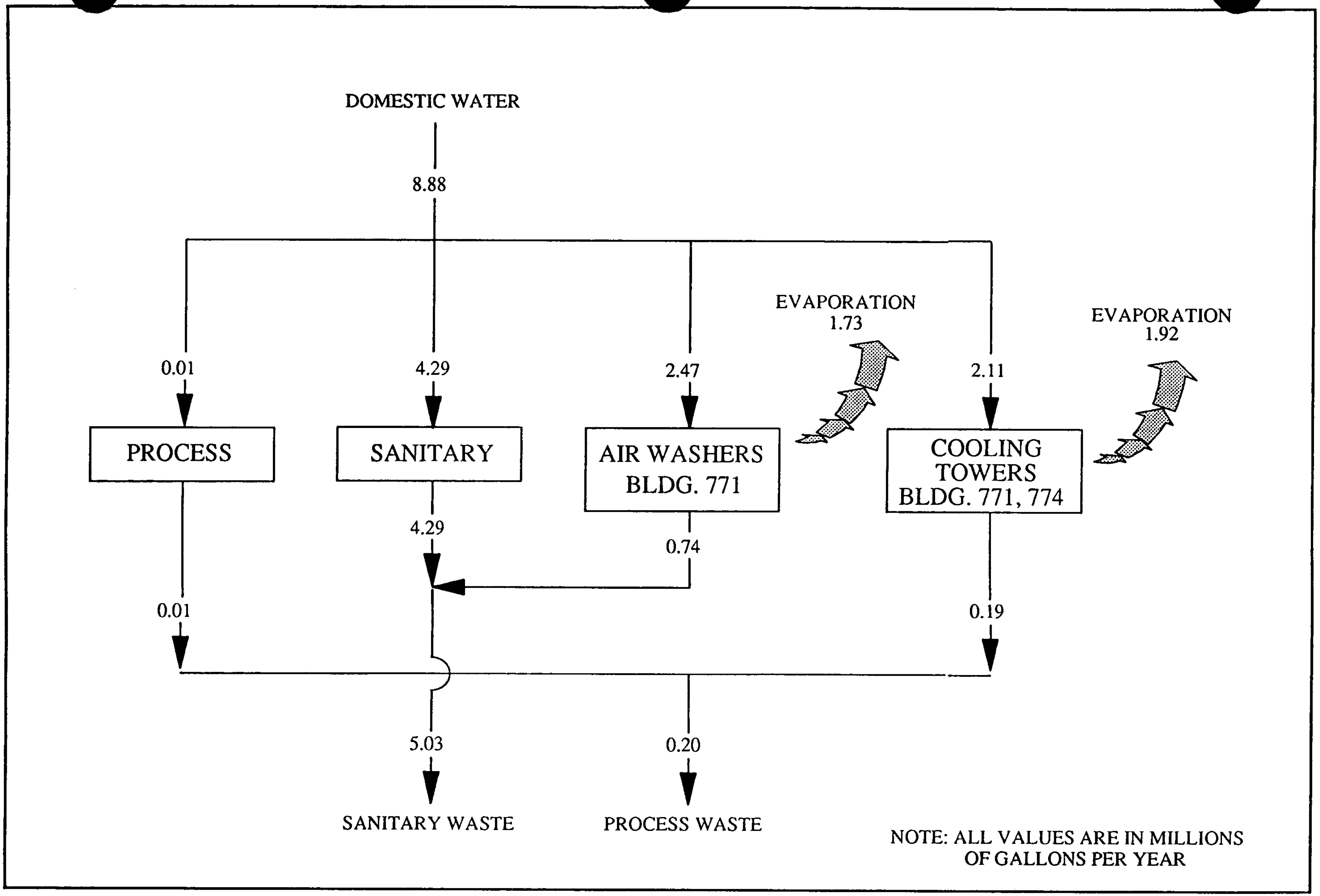
CY 89 Water Balance 771/774 Complex

Treated Sewage/Process Wastewater Recycle Study

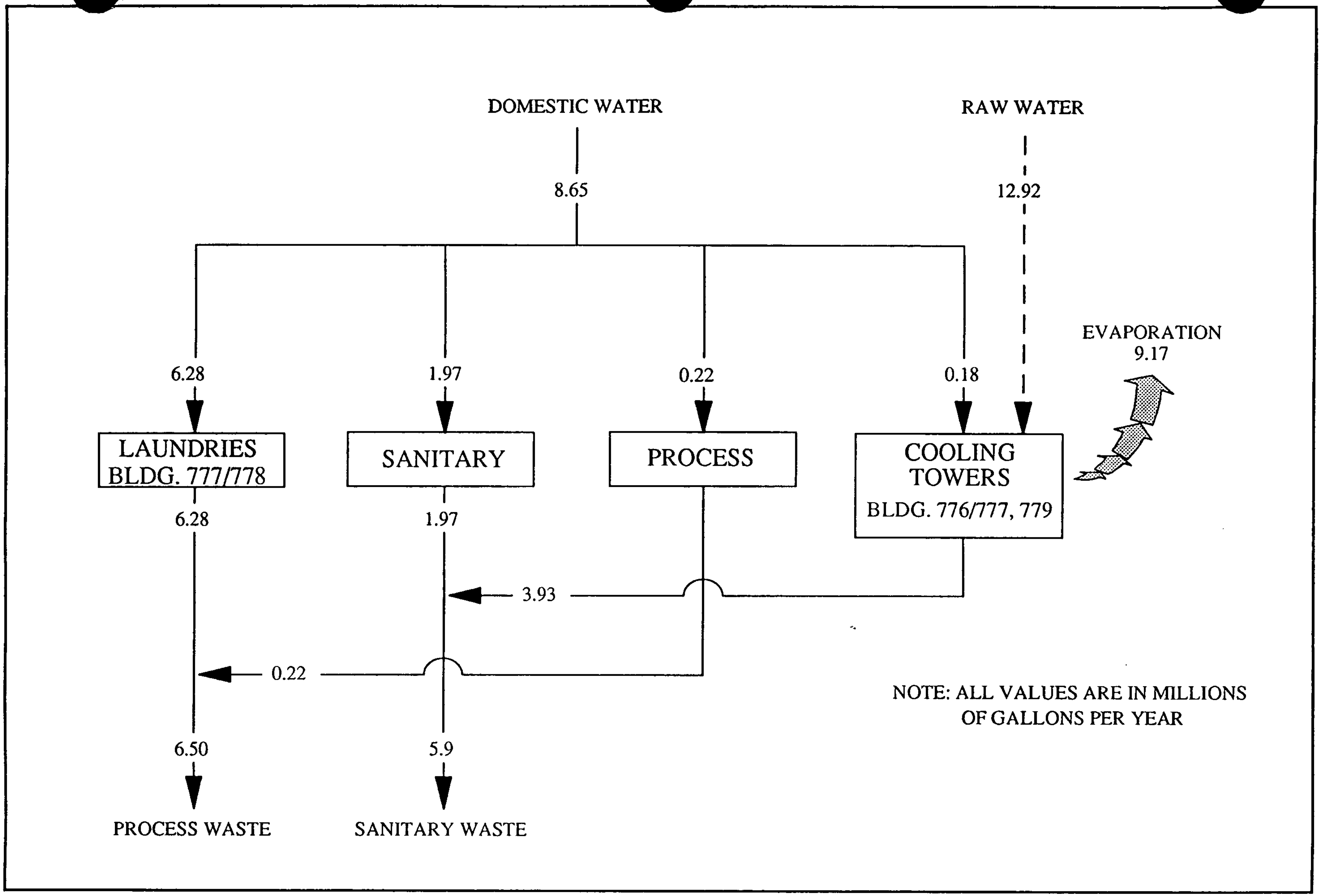
Zero-Offsite Water Discharge

PROJECT 20801.11

FIGURE C-6



CY 90 Water Balance 771/774 Complex



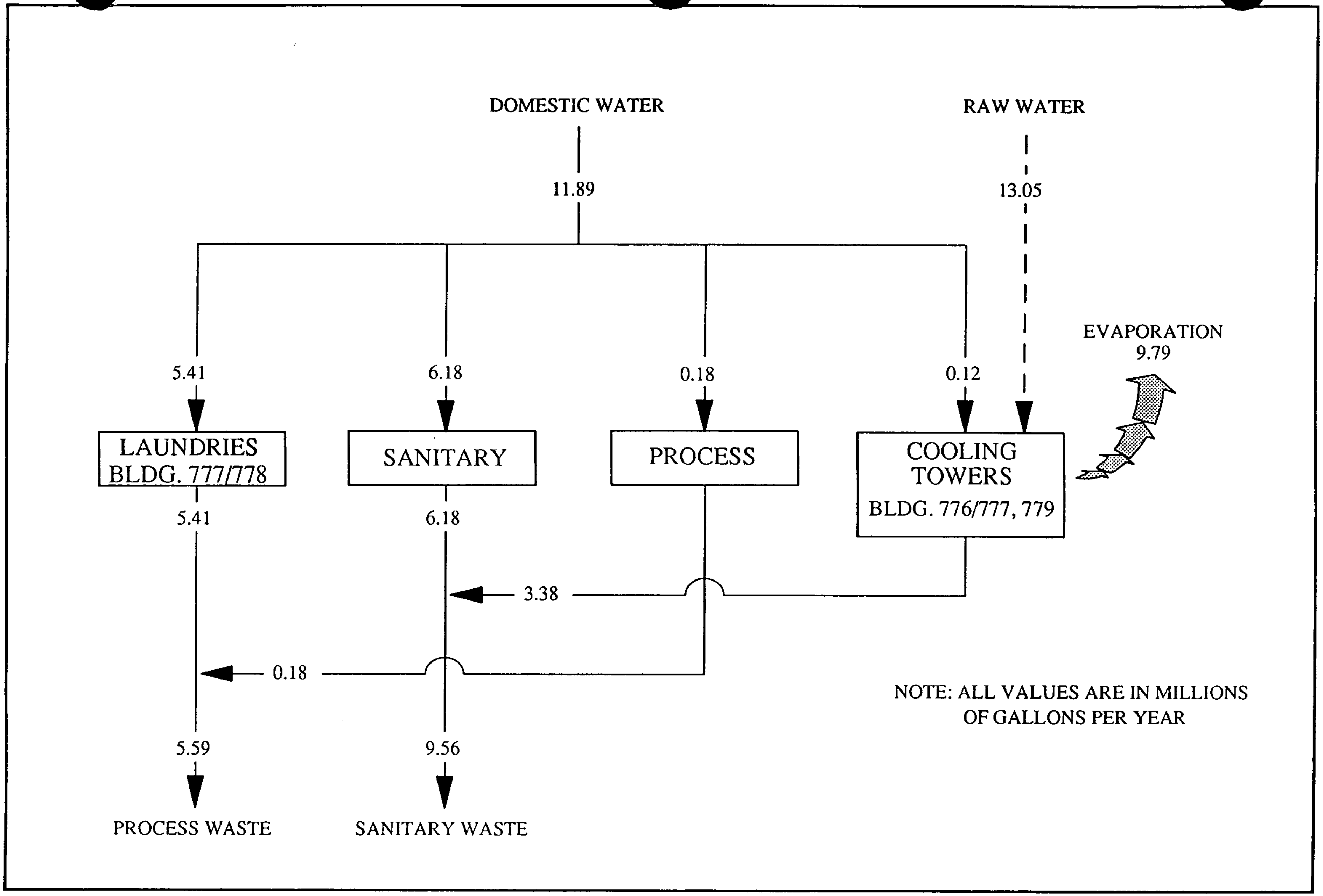
CY 89 Water Balance Buildings 776/777/778/779 Area

Treated Sewage/Process Wastewater Recycle Study

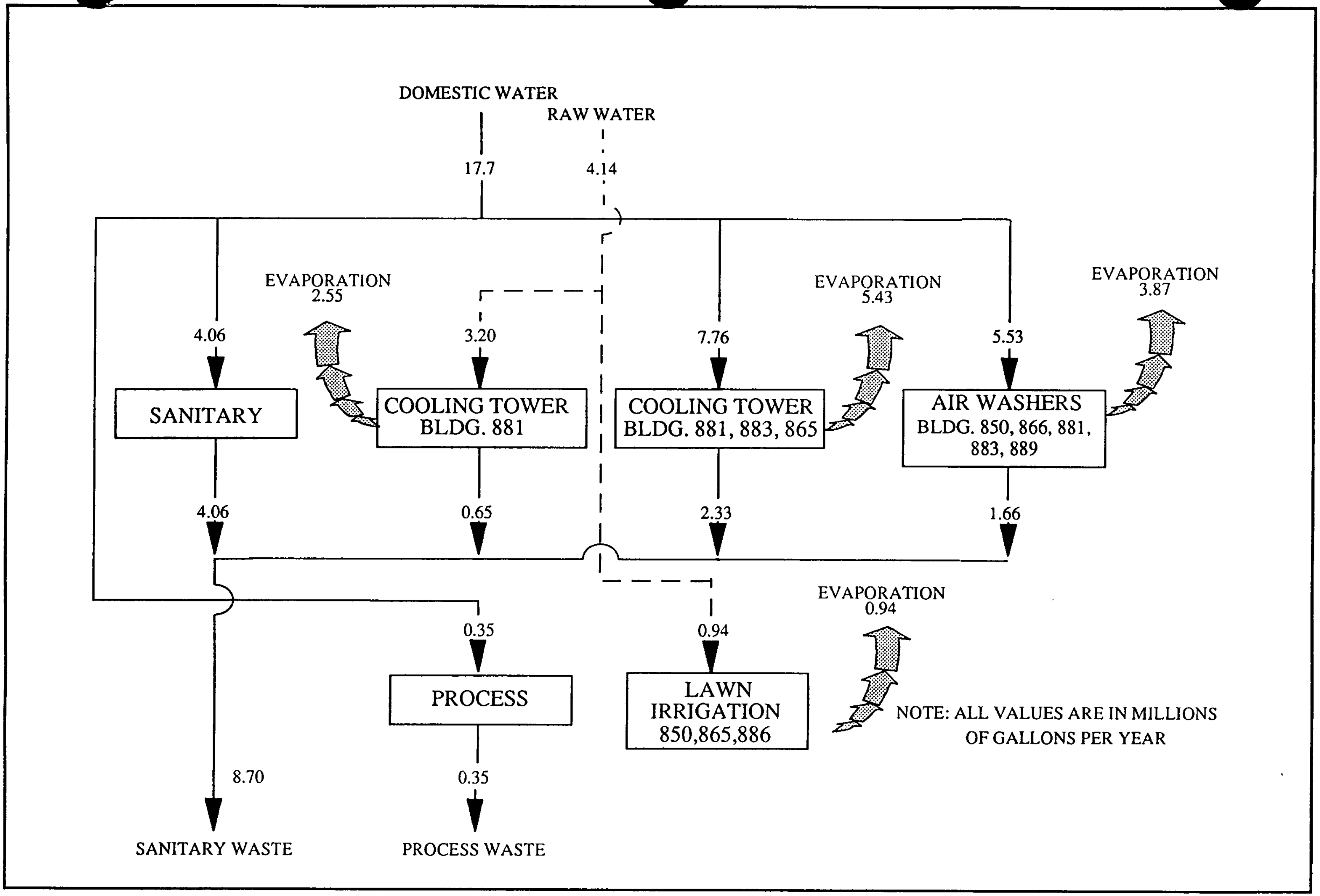
Zero-Offsite Water Discharge

PROJECT 20801.11

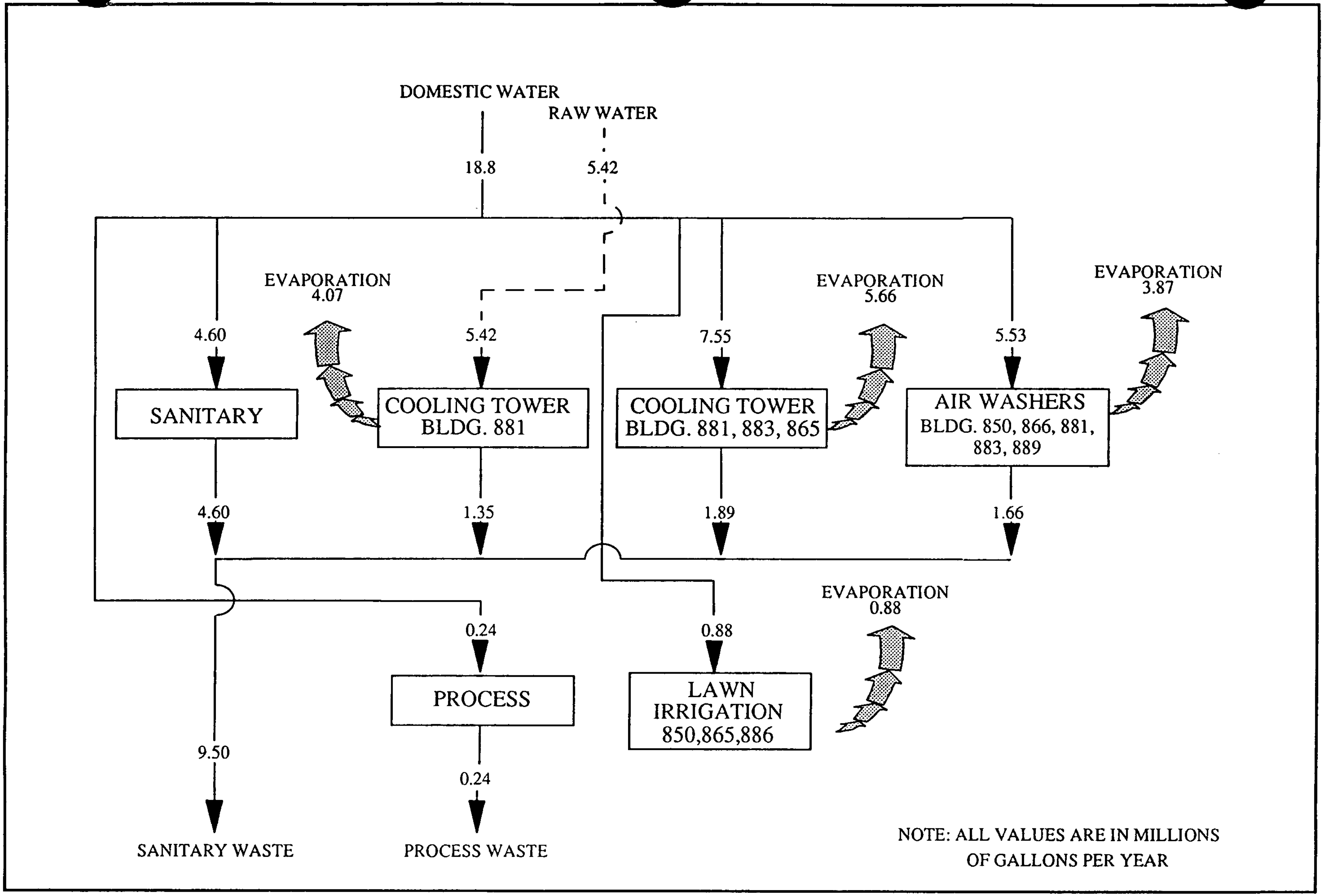
FIGURE C-7



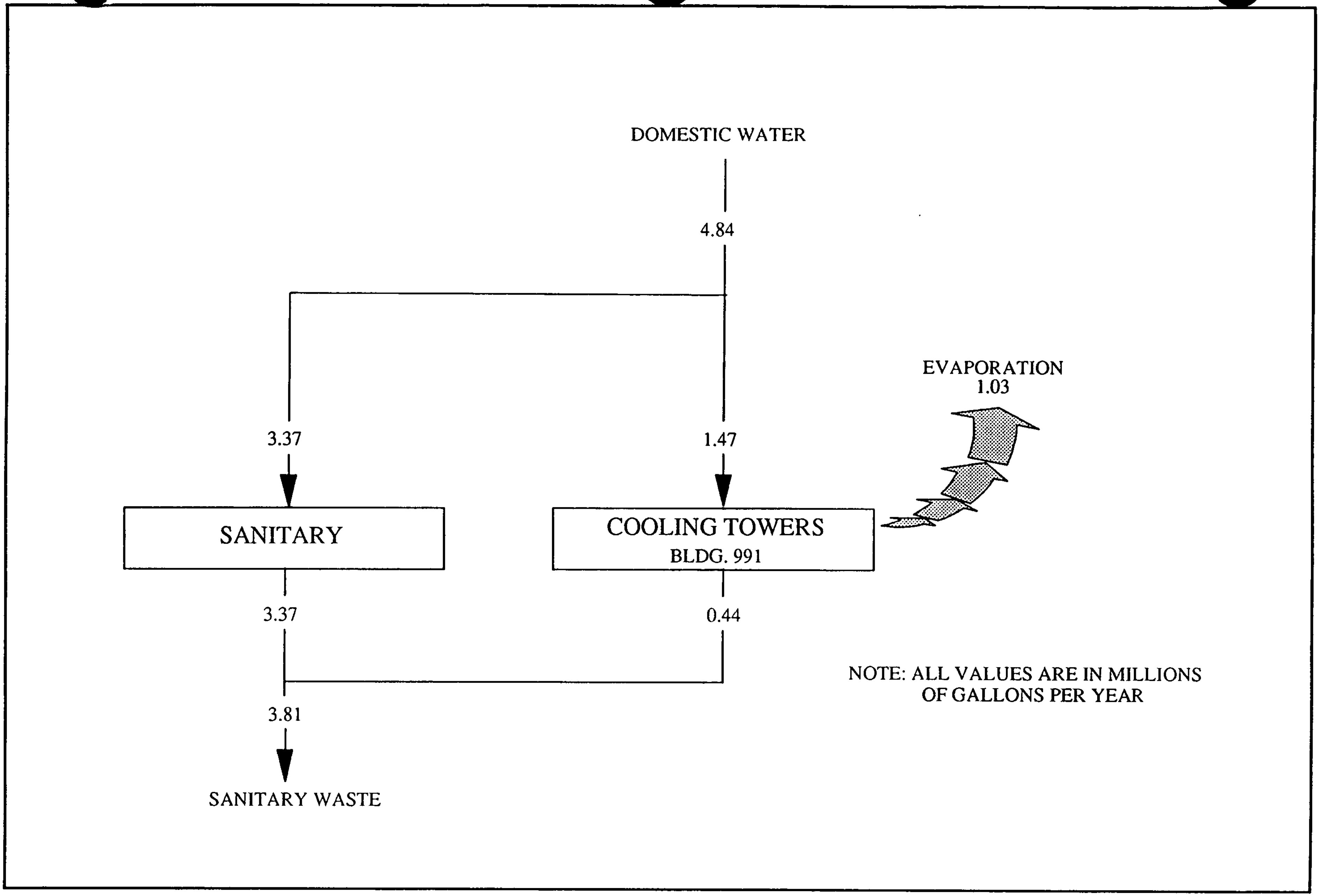
CY 89 Water Balance Buildings 776/777/778/779 Area



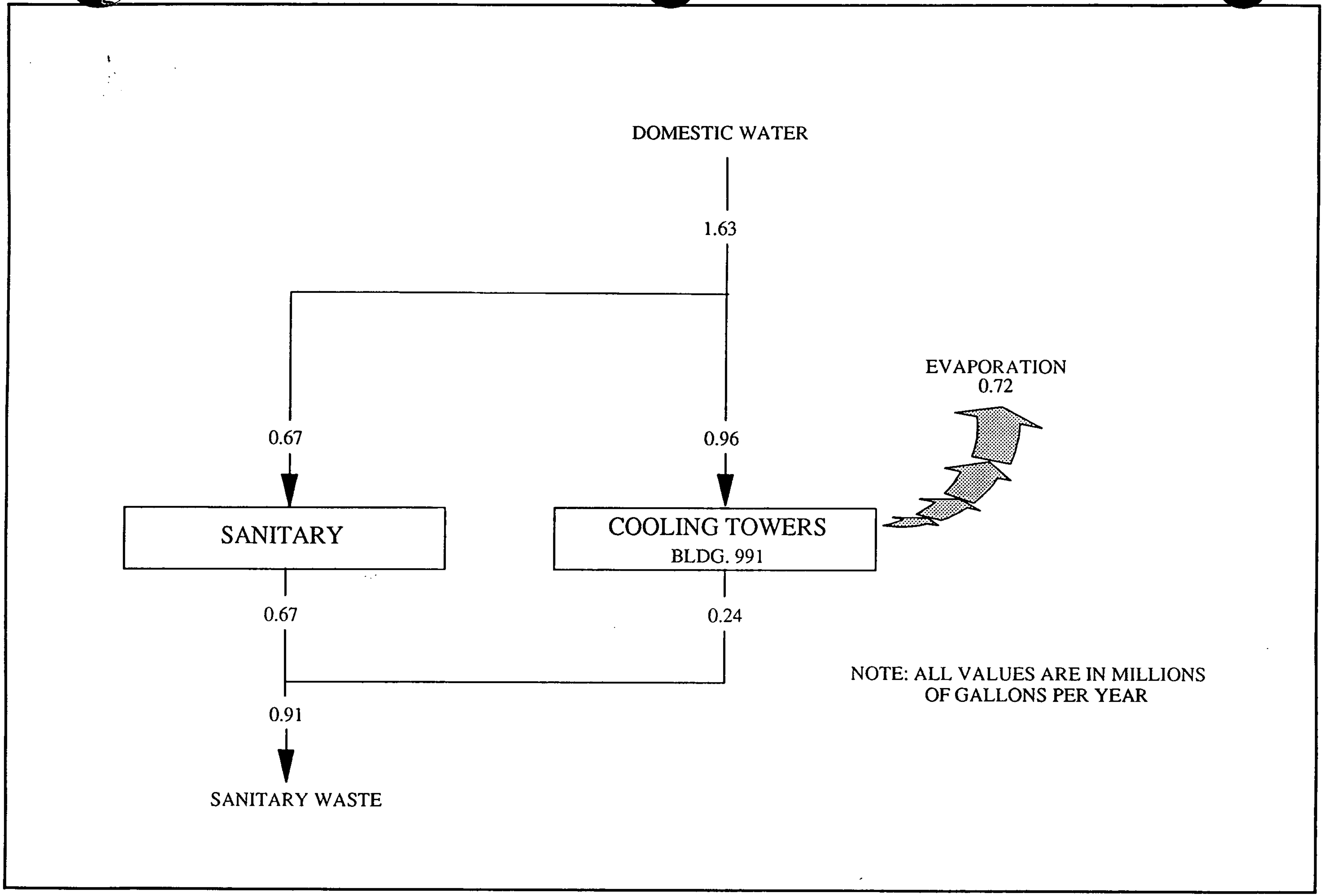
CY 89 Water Balance 800 Complex



CY 90 Water Balance 800 Complex



CY 89 Water Balance 900 Area



CY 90 Water Balance 900 Area